Integrated M.Sc. Chemistry Programme (CBCS) Curriculum

Department of Chemistry
School of Basic and Applied Sciences
Central University of Tamil Nadu
Thiruvarur 610 005

CENTRAL UNIVERSITY OF TAMIL NADU

VISION

To develop enlightened citizenship of knowledge society for peace and prosperity of individuals, nation and the world, through promotion of innovation, creative endeavors, and scholarly inquiry and to be a global destination of higher education and research.

MISSION

- To serve a beacon of change, through multi-disciplinary learning, for creation of knowledge community, by building a strong character and nurturing a value-based transparent work ethics, promoting creative and critical thinking for holistic development and self-sustenance for the people of India.
- The University seeks to achieve this objective by cultivating an environment of excellence in teaching, research and innovation in pure and applied areas of learning.

OBJECTIVES AND GOALS

- To disseminate and advance knowledge by providing instructional and research facilities in such branches of learning as it may deem fit
- To make special provisions for integrated courses in humanities, social sciences, science and technology in its educational programmes
- To take appropriate measures for promoting innovations in teaching-learning process and inter-disciplinary studies and research
- To educate and train manpower for the development of the country
- To establish linkages with industries for the promotion of science and technology
- To pay special attention to the improvement of the social and economic conditions and welfare of the people, their intellectual, academic and cultural development

DEPARTMENT OF CHEMISTRY

The Department of Chemistry started functioning from the year 2010 with five-year integrated M.Sc. Chemistry programme. The Department has the distinction of starting the first two-year PG program in Science at CUTN. Besides, the state-of-the-art PG and research laboratories were established. The Department is committed to excellence in chemistry by establishing research programmes for meeting scientific and technological challenges faced by the ever changing, science centered world of the 21st century.

The department is presently offering M.Sc., Integrated M.Sc., Post Graduate Diploma in Chemical Lab Technician (PGDCLT) and Ph.D. programmes. The Department provides ample opportunity for the students to accumulate a thorough fundamental knowledge of all fields of Chemistry. Meticulous lecture courses in the general areas of inorganic, organic and physical chemistry are conducted regularly in addition to the state-of-the-art laboratory courses which provides hands-on experience to the students at all levels.

The focus of the department is to instill the necessary spark and provide the scientific impetus so that the students can virtually experience the jiggling and wiggling of atoms and molecules. To enable students to have a glimpse of contemporary research, both in terms of academia and industry, the final year students in Chemistry will be completely engaged in project works. Our aim is to produce highly sought after and knowledgeable graduates for pursuing careers with academia, industry and government.

VISION AND MISSION OF THE DEPARTMENT

VISION

The Department envision establishing itself as a place of excellence for chemistry education and research programmes globally.

MISSION

- To bridge the gap between academia and industry by regularly updating the curriculum on par with recent developments in science and encourage doing in house projects
- To educate and invoke the students to deliver their maximum outputs in competitive examinations and meet industrial competences.
- To develop chemists with excellent analytical and synthetic skills through the curriculum with more laboratory components and industrial visits/internships.

1. THE PROGRAMME

The five-year Integrated M.Sc. Chemistry programme offered under CBCS by the Department of Chemistry, CUTN has ten semesters, which include 66 courses in total with an overall credit of 204. The first four semesters are a three-major stream. At the end of the fourth semester (two years) the student has the flexibility to slide over to any of the other two majors (Mathematics or Physics) based on his/her interest. Further, an exit option can be availed after six semesters (three years), wherein the student will be given a B.Sc. degree (with 130 credits). The duration of each semester shall be 90 working days, excluding examinations.

2. COURSE FEATURES

The 65 courses embrace core (Chemistry, Physics, and Biology/Mathematics), elective (Department selective), language, ability enhancement, skill enhancement courses, apart from research methodology and online MOOCs courses. In addition, an internship and research project courses are included in the curriculum.

3. ELIGIBILITY AND ADMISSION

A pass in the Plus two examination or equivalent of any recognized board in India with 60 % marks (Chemistry, Physics, Mathematics or Biology/ Botany / Zoology / Biotechnology) for General Category, 55% marks for OBC (NCL)/EWS and 50% marks for SC/ST/PWD candidates. The admission into the programme is done through the Common University Entrance Test (CUET-UG).

4. EXAMINATION

The assessment of a student pursuing the Integrated M.Sc. Chemistry programme shall be based on his/her performances in the Continuous Internal Assessment (CIA) and the End Semester Examinations (ESE). The distribution of marks for CIA and ESE are 40 % and 60 %, respectively. Irrespective of the score obtained by a student in the CIA, he/she must score a minimum of 50% in the ESE for passing a course.

4.1. CONTINUOUS INTERNAL ASSESSMENT (CIA)

The 40% marks for CIA shall be based on the students' performance in the following

(i) Periodical assessment tests (30 %)
(ii) Assignment and seminar presentations (10 %)

4.2. END SEMESTER EXAMINATION (ESE)

The ESE (maximum marks 60%) will be conducted by the University at the end of each semester (odd and even). The student must register for the first semester examination in order to be eligible for registration in the following semester examinations. A student shall register for subsequent semester examinations only after registering for the previous semester examinations.

4.3. QUESTION PAPER PATTERN

The question paper comprises of three sections, with maximum marks of 60 % and allowed time of 3 hours.

SECTION A (10 X 1 = 10) Answer ALL the questions

Ten Multiple Choice Questions, two questions from each unit. Four choices of answers in each question.

SECTION B (5 x 3 = 15) Answer any FIVE questions

Five questions to be answered from the given Choice of seven questions.

SECTION C (5 x 7 = 35) Answer ALL the questions

Answer all questions choosing either (a) or (b) from each question. One question from each unit.

5. PRACTICAL COURSE ASSESSMENT

The assessment of practical courses will be done on the basis of the students' performance in the laboratory, regular attendance, the number of experiments performed, on-time submission of observation and record notes, and written/viva-voce examinations.

6. ATTENDANCE

In each semester, the minimum attendance for a student to get eligible for appearing in the end semester examination is 75%. Upon failing the minimum requirement, the student shall abide by the University norms for eligibility.

7. INTERNSHIP

Students shall undergo summer internship (4 credit) during the VI or VIII semester for a period of minimum 2 months. They are encouraged to take up internship at industries/research labs/ institutes/universities (including CUTN). The evaluation of the internship would be based on external (70%, host institution) and internal (30%, Departmental) assessment.

8. RESEARCH PROJECT

Students shall undertake a research project (12 credit) during the 10^{th} semester in the 5^{th} year. The research guide shall be allotted to the students based on their research interest and academic ranking. The project report shall be submitted in the form of a dissertation at the end of the 10^{th} semester on or before the date notified by the Department. The student shall present the research project work and shall be evaluated by the Head of the Department and the project guide.

9. REVISION OF CURRICULUM

The Department of Chemistry shall revise and amend the regulations in the curriculum based on the feedback received from the stakeholders.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

The Integrated M.Sc. (IM.Sc.) Chemistry programme will enable the student to

PEO1: seamlessly integrate knowledge from other disciplines such as Physics, Mathematics/biology to enable interdisciplinary and multidisciplinary research.
PEO2: have societal, health, safety, and cultural issues relevant to the science practices and provide a strong foundation for acquiring advanced knowledge in chemistry
PEO3: acquire critical thinking supported by advanced analytical skills to address chemistry related problems.
PEO4: demonstrate the ability to perform accurate quantitative measurements with an understanding of the theory and use of sophisticated instruments, analyse and interpret.
PEO5: enhance skills for employability through activities, such as, seminar, communication skills, industrial visit, internship, and research project dissertation.

GRADUATE ATTRIBUTES

Disciplinary Knowledge: Content and pedagogical knowledge synchronised with the curriculum frameworks and policies
Communication Skills: Possess clarity in conveying the ideas
Critical Thinking: Capacity to apply analytical thought in the teaching and learning process
Problem Solving: Participate in the educational problem solving and applying the knowledge in the day-to-day professional endeavours.
Cooperation: Appreciate collaboration and cooperation among stakeholders of education.
ICT Skills: Selecting and integrating appropriate ICT skills for professional development.
Ethics: Doing what is right to society
Self-Directed Learning: Developing autonomy and self-regulation in teaching learning and professional development.
Reasoning: Ability to interpret and draw the conclusion from qualitative/quantitative data with open-mindedness
Creativity: Ability to produce new ideas
Societal and Environmental Concern: Performing an act or solving a problem with respect to societal and environmental concern
Lifelong Learning: Understands the need for learning and practices it throughout life

PROGRAMME OUTCOMES (POs)

On successful completion of integrated M.Sc. programme, the student will be able to

PO1: Think critically and analyse problems.
PO2: Prepare and present scientific and technical information resulting from laboratory outputs.
PO3: Design methodologies, analyse, and evaluate innovative scientific research problems.
PO4: Pursue higher education / become an employee / entrepreneur.
PO5: Work independently as well as in a team.

POs	PEO1	PEO2	PEO3	PEO4	PEO5
PO1	3	3	3	3	3
PO2	3	2	3	3	2
PO3	2	3	3	2	2
PO4	3	3	3	3	3
PO5	3	2	2	3	3

PROGRAMME SPECIFIC OUTCOMES (PSOs)

Upon successful completion of integrated M.Sc. Chemistry programme, the student will be able to

PSO1: Acquire the knowledge of fundamental chemistry concepts and recent advancement in the scientific field.

PSO2: Understand the features of molecules in organic /inorganic/physical domain

PSO3: Develop computational and experimental skills to explore molecular level phenomena.

PSO4: Apply technical skill in a sophisticated laboratory environment and secure challenging position in industry and academics.

PSO5: Enhance employability through laboratory activities, solving problems and co-curricular activities

COURSE STRUCTURE

No	Course Code	Course Title	Course Type	Credit	Hours / week	Marks	
						Int	Ext
SEMESTER - I							
1	CHE1011	General Chemistry	Theory	3	3	40	60
2	CHE1012	General Chemistry Laboratory	Practical	2	3	100	
3		Second Major	Theory	3	3	40	60
4		Second Major Laboratory	Practical	2	3	100	
5		Third Major	Theory	3	3	40	60
6		Third Major Laboratory	Practical	2	3	100	
7		English-I	Theory	3	3	40	60
8		Ability Enhancement Course	Theory	2	2	40	60
Total				**20**	**23**		
SEMESTER - II							
9	CHE1021	Physical Chemistry-I	Theory	3	3	40	60
10	CHE1022	Physical Chemistry Laboratory-I	Practical	2	3	100	
11		Second Major	Theory	3	3	40	60
12		Second Major Laboratory	Practical	2	3	100	
13		Third Major	Theory	3	3	40	60
14		Third Major Laboratory	Practical	2	3	100	
15		English-II	Theory	3	3	40	60
16		Ability Enhancement Course	Theory	2	2	40	60
Total				**20**	**23**		
SEMESTER – III							
17	CHE1031	Inorganic Chemistry-I	Theory	3	3	40	60
18	CHE1032	Inorganic Chemistry Laboratory-I	Practical	2	3	100	
19		Second Major	Theory	3	3	40	60
20		Second Major Laboratory	Practical	2	3	100	
21		Third Major	Theory	3	3	40	60
22		Third Major Laboratory	Practical	2	3	100	
23		Language-I	Theory	3	3	40	60
24		Ability Enhancement Course	Theory	2	2	40	60
Total				**20**	**23**		
SEMESTER – IV							
25	CHE1041	Organic Chemistry-I	Theory	3	3	40	60
26	CHE1042	Organic Chemistry Laboratory-I	Practical	2	3	100	
27		Second Major	Theory	3	3	40	60
28		Second Major Laboratory	Practical	2	3	100	
29		Third Major	Theory	3	3	40	60
30		Third Major Laboratory	Practical	2	3	100	
31		Language-II	Theory	3	3	40	60
32		Ability Enhancement Course	Theory	2	2	40	60

Total				**20**	**23**		
SEMESTER – V							
33	CHE1051	Analytical Methods in Chemistry	Theory	4	4	40	60
34	CHE1052	Inorganic Chemistry-II	Theory	4	4	40	60
35	CHE1053	Organic Chemistry-II	Theory	4	4	40	60
36	CHE1054	Physical Chemistry-II	Theory	4	4	40	60
37	CHE1055	Inorganic Chemistry Laboratory-II	Practical	2	3	100	
38	CHE1056	Organic Chemistry Laboratory-II	Practical	2	3	100	
39	CHE1057	Physical Chemistry Laboratory-II	Practical	2	3	100	
40		Skill Enhancement Course	Theory	2	2	40	60
Total				**24**	**27**		

SEMESTER – VI							
41	CHE1061	Inorganic Chemistry – III	Theory	4	4	40	60
42	CHE1062	Organic Chemistry – III	Theory	4	4	40	60
43	CHE1063	Physical Chemistry – III	Theory	4	4	40	60
44	CHE1064	Inorganic Chemistry Laboratory-III	Practical	2	3	100	
45	CHE1065	Organic Chemistry Laboratory-III	Practical	2	3	100	
46	CHE1066	Physical Chemistry Laboratory-III	Practical	2	3	100	
47		Skill Enhancement Course	Theory	2	3	40	60
Total				**20**	**24**		
48	CHE1067	Project (for Students opting exit)	Project	6		100	
Total (for students opting exit)				**26**			

SEMESTER – VII							
49	CHE1071	Inorganic Chemistry-IV	Theory	4	4	40	60
50	CHE1072	Organic Chemistry-IV	Theory	4	4	40	60
51	CHE1073	Physical Chemistry-IV	Theory	4	4	40	60
52	CHE1074	Organic Chemistry Laboratory-IV	Practical	4	7	100	
53	CHEEXX	Elective	Theory	4	4	40	60
Total				**20**	**21**		
SEMESTER – VIII							
54	CHE1081	Inorganic Chemistry-V	Theory	4	4	40	60
55	CHE1082	Organic Chemistry-V	Theory	4	4	40	60
56	CHE1083	Physical Chemistry-V	Theory	4	4	40	60
57	CHE1084	Physical Methods in Chemistry-I	Theory	4	4	40	60
58	CHE1085	Physical Chemistry Laboratory-IV	Practical	4	7	100	
Total				**20**	**21**		

SEMESTER – IX							
59	CHE1091	Physical Methods in Chemistry-II	Theory	4	4	40	60
60	CHE1092	Organic Chemistry-VI	Theory	4	4	40	60
61	CHE1093	Physical Chemistry-VI	Theory	4	4	40	60
62	CHE1094	Research Methodology (Regular / MOOCS course)*	Theory	4	4	40	60
63	CHEEXX	Elective	Theory	4	4	40	60

64	CHE1095	Inorganic Chemistry Laboratory-IV	Practical	4	7	100
65	CHE1096	Internship#	Practical	4	#	100
Total				**28**	**27#**	
*The student shall attend the online course during any one of the semesters from V to VIII. #Students must undergo summer internship during VI or VIII semester for a period of minimum 2 months. They are encouraged to take up internship at industries/research labs/ institutes/universities (including CUTN).						

SEMESTER – X						
66	CHE1101	Research Project*	Project	12	*	100
Total				**12**		
*Throughout the semester						

TOTAL CREDIT		**BSc**	Total: **130** credits for **B.Sc. Exit option candidates**. Those who opt for the exit option should give in writing to the department with an endorsement from the parent at the end of second year (fourth semester).	**MSc**	Total: **204** credits for Int. MSc candidates. The Int. MSc students with Mathematics background will be given Mathematics and Physics as other majors, whereas Int. MSc students with Biology background will be given Physics and biology as other major subjects.
1	Theory	88		140	
2	Practical	36		48	
3	Internship	--		04	
4	Project	06		12	
Total		**130**		**204**	

Semester: I **Course Type: Theory** **Course Code: CHE1011**
Credit: 3 **Course Title: General Chemistry**

Course Outcomes		Level
CO-1	Know the basic concepts of atomic structure and stability of orbitals	**Understand**
CO-2	Understand the various types of chemical bonding and to draw MO diagram	**Apply**
CO-3	Learn the nomenclature of organic compounds based on various functional groups	**Apply**
CO-4	Understand the electronic effects, reactive intermediates and their stability	**Understand**
CO-5	Outline the laws of thermodynamics & basic aspects of various processes and to know the fundamentals of ionic equilibria	**Remember**

Unit-I Atomic Structure

Rutherford atomic model, Bohr theory of hydrogen atom, Hydrogen atom spectra, Sommerfield theory, Electromagnetic radiation, descriptions for λ, υ and velocity. Particle and wave character of electrons, review of black body radiation, Planck's quantum theory, photoelectric effect and Compton effect. DeBroglie's equation, Davisson-Germer experiment, Heisenberg's uncertainty principle. Need of a new approach to atomic structure. Introduction to Quantum mechanics Schrodinger wave equation (no derivation), Quantum numbers, Pauli's exclusion principle, Orbits and Orbitals. Rules for filling electrons in various orbitals, electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations.

UNIT-II Periodic properties

Periodic properties – classification of elements as s, p, d and f-block elements – variation of atomic volume – atomic and ionic radii – ionization potential – electron affinity and electronegativity along period and groups – variation of metallic characters - Factors affecting the periodic properties. Periodic table anomalies and variations in atomic radius, ionic radius, electronic configuration, electron affinity and electronegativity, ionization energy and metallic character of elements along the group and periods and their influences on stability, colour, coordination number, geometry, physical and chemical properties.

Unit-III Functional groups and Nomenclature of organic compounds

Classification and nomenclature of organic compounds. Introduction to functional groups. Structure, nomenclature and isomerism in alkanes, General methods of preparation and reactions of alkanes, alkenes and alkynes. Sources, nomenclature and preparation of cycloalkanes. Stability of cyclopropane to cyclooctane. Elimination reactions E1 and E2: Hofmann vs. Saytzeff rule. Addition reaction with hydrogen halide (Markovnikov's and Anti-Markovnikov's rule) and ozonolysis. Oxidation and reduction in organic chemistry.

Unit-IV Fundamentals of Organic Chemistry

Structure of organic molecules based on hybridization, Physical Effects, Electronic Displacement: Inductive Effect, Electromeric Effect, Mesomeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis. Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals-generation, stability and identification methods.

Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values.

Unit-V Thermodynamics and Ionic Equilibria

Review of thermodynamics and the Laws of Thermodynamics, Important principles and definitions of thermochemistry. Concept of standard state: standard enthalpy of formation, integral enthalpy and differential enthalpy of solution. Work of expansion, work of compression, maximum and minimum quantities of work, reversible and irreversible transformations of energy, isothermal and adiabatic changes. Thermodynamic state functions and Joule Thomson experiment. Variation of enthalpy of a reaction with temperature: Kirchhoff's equation.

Ionic Equilibria: Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, pH scale, Henderson's equation, Buffer solutions and their types. Applications of buffer solutions.

Reference Books

1. D. D. Ebbing, General Chemistry, 10th Ed, Cengage Learning India Pvt. Ltd., 2013.
2. J. D. Lee, Concise Inorganic Chemistry, Wiley, 5th Ed., 2016.
3. G. Solomons, T. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
4. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
5. I. L. Finar, Organic Chemistry, Vol I, 6th Ed, Pearson Education, 2002.
6. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
7. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford University Press, 2014.
8. Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8nd Ed., Wiley Publications, 2019
9. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Ed., Orient Longman, New Delhi, 1988.
10. P. Atkins, J. Paula, The Elements of Physical Chemistry, 7th Ed. Oxford University Press, 2017.
11. B. R. Puri, L. R. Sharma, M. S. Pathania, Elements of Physical chemistry, Vishal Pub. Co. Jalandhar, 2017.
12. G. K. Vemulapalli, Physical Chemistry, Prentice-Hall of India Pvt. Ltd. 1997.
13. W. J. Moore, Basic Physical Chemistry, Orient Longman, 1963.
14. F. A. Alberty and R. J. Silby, Physical Chemistry, 4th Ed., John Wiley, 2004.
15. G. M. Barrow, Physical Chemistry, 5th Ed., Tata McGraw Hill, 2007.
16. G. W. Castellan, Physical Chemistry, 3rd Ed, Narosa Publishing House, New Delhi, 2004.
17. R. P. Rastogi, R. R. Misra, An Introduction to Chemical Thermodynamics, 6th Ed., Vikas Pub. Pvt. Ltd. 2003.
18. J. Rajaram and J. C. Kuriakose, Thermodynamics, Shoban Lal Nagin Chand & Co., 1986.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	1	1	2	1
2	2	1	2	2	1
3	2	1	1	2	1
4	3	1	2	2	1
5	3	1	2	2	1

Semester: I **Course Type: Practical** **Course Code: CHE1012**
Credit: 2 **Course Title: General Chemistry Laboratory**

Course Outcomes		Level
CO-1	Estimate heat transfer of various reactions and thermodynamic parameters	**Analyze**
CO-2	Use pH measurements for assessing the acidic and basic properties	**Apply**
CO-3	Prepare buffer solutions and standards	**Apply**
CO-4	Estimate the ionic equilibrium in a given system	**Analyze**

Thermochemistry:

1. Determination of heat capacity of calorimeter for different volumes.
2. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
3. Determination of enthalpy of ionization of acetic acid.
4. Determination of integral enthalpy of solution of salts (KNO_3, NH_4Cl).
5. Determination of enthalpy of hydration of copper sulphate.
6. Study of the solubility of benzoic acid in water and determination of ΔH.

Ionic Equilibria:

1. Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps using pH-meter.
2. Preparation of buffer solutions:
   (a) Sodium acetate-acetic acid
   (b) Ammonium chloride-ammonium hydroxide
3. Measurement of the pH of buffer solutions and comparison of the values with theoretical values.

Reference books:

1. B. Viswanathan, Practical Physical chemistry, Viva Pub., 2005.
2. Saroj Kumar Naba Kumar, Physical Chemistry Practical, New Central Book Agency, 2012.
3. A.M. James, F.E. Prichard Practical Physical Chemistry Paperback, 1974.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	2	1	3
2	1	3	1	1	3
3	2	3	2	1	3
4	2	3	3	2	3

Semester: II **Course Type: Theory** **Course Code: CHE1021**
Credit: 3 **Course Title: Physical Chemistry-I**

Course Outcomes		Level
CO-1	To acquire basic knowledge of Chemical Equilibrium and chemical kinetics	**Remember**
CO-2	To classify types of solutions and colligative properties	**Apply**
CO-3	To understand the chemical reactions in the batteries and corrosion	**Understand**
CO-4	To explore the surface phenomena and electrochemical cells	**Analyze**

Unit-I Chemical Equilibrium and Kinetics

Chemical Equilibrium: Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between ΔG and ΔG_0, Le Chatelier's principle. Relationships between Kp, Kc and Kx for reactions involving ideal gases.

Kinetics: The concept of reaction rates, Order and Molecularity. Factors affecting reaction rates. Integrated rate equations for zero, first and second order reactions. Half–life of a reaction. Experimental determination of order of a reaction. Concept of activation energy and Arrhenius equation. Collision theory and Activated Complex theory of bimolecular reactions.

Unit-II Solutions

Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions. Vapour pressure-composition and temperature composition curves of ideal and non-ideal solutions. Lever rule. Azeotropes. Critical solution temperature (CST); effect of impurity on partial miscibility of liquids. Immiscibility of liquids- Principle of steam distillation. Nernst distribution law and its applications, solvent extraction. Colligative properties- relative lowering of vapour pressure, osmosis, law of osmotic pressure, derivation of elevation of boiling point and depression in freezing point. Determination of molecular masses using colligative properties. Abnormal molecular masses, molecular dissociation- degree of dissociation- molecular association.

Unit-III Phase Equilibrium

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs Phase Rule and its thermodynamic derivation. Derivation of Clausius – Clapeyron equation and its importance in phase equilibria. Phase diagrams of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting points (lead-silver, $FeCl_3$-H_2O and Na-K only).

Unit-IV Surface Chemistry

Surface Chemistry: Adsorption-types-chemical and physical, characteristics of adsorption. Theories of catalysis- intermediate compound formation theory and adsorption theory. Fruendlich and Langmuir adsorption isotherms – BET theory multilayer adsorption – BET equation (derivation not required) – determination of surface using BET theory –Ion-exchange adsorption, water softening, applications of adsorption.

Unit-V Electrochemistry-I

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Kohlrausch's law of independent migration of ions. Ionic mobility.

Transference number and its experimental determination using Hittorf and Moving boundary methods. hydrolysis constant of a salt.
EMF of a cell, Types of electrodes. Standard electrode potential. Electrochemical series. Nernst equation and its importance. Thermodynamics of a reversible cell, calculation of thermodynamic properties: ΔG, ΔH and ΔS from EMF data. Calculation of equilibrium constant from EMF data. Liquid junction potential and salt bridge. Concentration cells with transference and without transference (qualitative). Corrosion of metals – forms of corrosion, corrosion monitoring and prevention methods.

Reference Books:

1. G. M. Barrow, Physical Chemistry Tata McGraw Hill 2007.
2. G. W. Castellan, Physical Chemistry 4th Edn. Narosa 2004.
3. J. C. Kotz, P.M. Treichel & J.R. Townsend, General Chemistry Cengage Learning India Pvt. Ltd., New Delhi 2009.
4. R. P. Rastogi, R. R. Mishra, An Introduction to Chemical Thermodynamics, 6thEdn., Vikas Pub. Pvt. Ltd. 2003.
5. B. H. Mahan, University Chemistry 3rd Edn. Narosa 1998.
6. R. H. Petrucci, General Chemistry 5th Edn. Macmillan Publishing Co.: New York 1985.
7. B. S. Bahl, G. D. Tuli and A. Bahl, Essentials of Physical Chemistry, S. Chand & Company Ltd, New Delhi, 12th Edn.,2011.
8. B. R. Puri, L.R. Sharma and M. S. Pathania, Principles of Physical Chemistry, 48th Edn. Vishal Publishing Co, 2019.
9. K. L. Kapoor, A Textbook of Physical chemistry, Volumes 1, 6th Edn. Macmillan India Ltd, 2020.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	1
2	3	1	2	1	1
3	2	1	2	1	1
4	3	1	3	1	1

Semester: II **Course Type: Practical** **Course Code: CHE1022**
Credit: 2 **Course Title: Physical Chemistry Laboratory-I**

Course Outcomes		Level
CO-1	To experiment with the basic skills required for wet lab chemistry	**Analyze**
CO-2	To apply or correlate the physical chemistry concepts with the experiments	**Apply**
CO-3	To identify or perform the appropriate experiments for the measurements of concentration	**Understand**
CO-4	To execute solvent extraction process and eutectic experiments	**Apply**

Partition Coefficient:

1. Determine the distribution of a solute in two immiscible liquids.
2. Study of the equilibrium of the following reactions by the distribution method:
   $I_2(aq) + I^-(aq) \rightarrow I_3^-(aq)$

Phase equilibria:

1. Construction of the phase diagram of a binary system (simple eutectic) using cooling curves.
2. Determination of the critical solution temperature and composition of the phenol water system and study of the effect of impurities on it.

Potentiometry: Perform the following potentiometric titrations:

1. Strong acid vs. strong base
2. Weak acid vs. strong base

Conductance: conductometric titrations:

1. Strong acid vs. strong base
2. Weak acid vs. strong base

Reference Books

1. J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2001.
2. G. W. Garland, J. W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8th Edn. McGraw Hill, 2009.
3. A. M. James and F.E. Prichard Practical Physical Chemistry Paperback, 1974.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	3	2	1	3
2	2	3	1	1	3
3	2	3	3	1	3
4	1	3	2	1	3

Semester: III **Course Type: Theory** **Course Code: CHE1031**
Credit: 3 **Course Title: Inorganic Chemistry-I**

Course Outcomes		Level
CO-1	Understand various bonding theories - VB and MO theories	**Understand**
CO-2	Know about basic metallurgical processes.	**Analyze**
CO-3	Acquire the knowledge of acid, base and redox reactions	**Understand**
CO-4	Understand the chemistry of s - block elements and its complexes	**Understand**
CO-5	Enable the students to acquire knowledge in the theory behind the volumetric analysis, this leads them to develop the knowledge in the principles of concentration, primary and secondary standards and qualitative analysis of inorganic ions	**Remember**

Unit-I Chemical Bonding and Molecular Structure

Ionic bond - Properties of ionic compounds, factors favoring the ionic compounds ionization potential - electron affinity - electronegativity - Lattice energy - Born-Haber Cycle - Pauling and Mulliken's scales of electronegativity - Polarizing power and Polarizability - Partial ionic character from electronegativity. Transition from ionic to covalent character and vice versa - Covalent character of ionic compounds - Fajan's rules - Covalent bond - structure and bonding of homo and heteronuclear molecules - Hydrogen bonding - Its nature, types, effect on properties - Intermolecular forces - London forces and van der Waals forces - ion dipole-dipole interactions. VSEPR Theory - Principles and hybridization- Shapes of simple inorganic molecules ($BeCl_2$, BF_3, $SiCl_4$, PCl_5, SF_6, IF_7, H_2O, NH_3, XeF_6) - MO theory of homo-nuclear diatomic molecules of 1st and 2nd periods and heteronuclear diatomic molecules such as HF, CO, NO and NO^+. Polyatomic molecules BeH_2, BH_3 and NH_3 - Walsh diagram. Comparison of VB and MO approaches.

Unit-II Acids, Bases, and Redox Reactions

Theory of Acid bases: Bronsted-Lowry theory, Lewis theory, Lux-Flood definition, Usanovich definition, HSAB theory and symbiosis - Gas phase acid-base chemistry – Solvent levelling effects. Chemistry in aqueous and Non-aqueous Solvents - super acids - molten salts. Oxidation and reduction reactions - oxidation number concept, balancing redox equations by oxidation number method and ion-electron method - equivalent weight of oxidizing and reducing agents. Disproportionation and com-proportionating reaction, Redox stability in water: Frost-Ebsworth, Latimer and Pourbaix diagrams, applications of redox reactions to extraction of elements from their ores - Ellingham diagram.

UNIT-III s-Block elements

Position of hydrogen in the periodic table, General characteristics of s-block elements- Compounds of s-block metals - oxides, hydroxides, peroxides, superoxide's - preparation and properties - oxo salts - carbonates - bicarbonates - nitrates - halides and polyhalides. Anomalous behavior of Li and Be - extraction of beryllium - physical and chemical properties of Be - Uses - Extraction of Mg - physical and chemical properties - Uses. Complexes of s-block metals - complexes with crown ethers - biological importance sodium and potassium - Organometallic compounds of Li and Be.

UNIT-IV Metallurgy

Occurrence of metals-basic metallurgical operations and metallurgy process - General methods involved in extraction of metals- concentration of ores - froth floatation, magnetic separation, calcination, roasting, smelting, flux, aluminothermic process. Extraction processes - Chemical reduction - electrolytic reduction - metal displacement - refining methods - distillation - fractional crystallization - electrolysis. Zone reining - van Arkel de Boer methods - electrolytic refining - ion exchange method - muffle furnace - chemical properties - important compounds and uses of Cr, Mn, Co, Ni and Zn.

UNIT-V Principles of Quantitative and Qualitative Analysis

Qualitative Inorganic Analysis - Dry Test, flame test, cobalt nitrate test - wet confirmatory test for acid radicals, interfering acid radicals - elimination of interfering acid radicals. Solubility product, common ion effect, complexation, oxidation-reduction reactions involved in identification of anions and cations - separation of cations into groups - Semi micro analysis of simple salts. Types of titrations. Requirements for titrimetric analysis. Concentration systems: Molarity, molality formality, normality, wt%, ppm, milli-equivalence and millimoles -problems. Primary and secondary standards, criteria for primary standards, preparation of standard solutions, standardization of solutions. Limitation of volumetric analysis, endpoint and equivalence point. Neutralisation-titration curve, theory of indicators, Choice of indicators. Use of phenolphthalein and methyl orange. Complexometric titrations: Stability of complexes, titration involving EDTA. Metal ion indicators and characteristics. Problems based on titrimetric analysis. General principle: General principles of inorganic qualitative analysis.

Reference Books:

1. B. H. Mahan, University Chemistry 3rd Ed. Narosa. 1998.
2. R. H. Petrucci, General Chemistry 5th Ed. Macmillan Publishing Co., New York,1985.
3. C. E. Housecraft and A. G. Sharpe, Inorganic Chemistry, 4th edition, Pearson, 2012.
4. D. Shriver, P.W. Atkins, Inorganic Chemistry, W.H. Freeman and Company,5th Ed, 2009
5. J. D. Lee, Concise Inorganic Chemistry, Wiley, 5th edn., 2016.
6. C. N. R. Rao, Understanding Chemistry, University Press (India) Ltd., 2001
7. R. P. Sarkar, General and Inorganic Chemistry Part- I, 3rd revised edition; New Central Book Agency, 2011.
8. B. E. Douglas, D.H. McDaniel, &J.J. Alexander, Concepts and Models in Inorganic Chemistry, John Wiley & Sons. 2010
9. J. E. Huheey, E. A. Keiter, R. L. Keiter, & O. K. Medhi, Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education India, 2006
10. G. Wulfsberg, Inorganic Chemistry, Viva Books Pvt. Ltd. 2014
11. F. A. Cotton, G. Wilkinson, C. A. Murilloand, M. Bochmann, Advanced Inorganic Chemistry, 6th Edition, John Wiley & Sons, 2008.
12. N. N. Greenwood and A. Earnshaw, Chemistry of the Elements, 2nd Ed, Elsevier, 2005.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	3
2	1	1	1	1	3
3	3	2	3	1	3
4	2	1	2	1	3
5	2	1	3	1	2

Semester: III **Course Type: Practical** **Course Code: CHE1032**
Credit: 2 **Course Title: Inorganic Chemistry Laboratory-I**

Course Outcomes		Level
CO-1	Quantitatively estimate the amount of metal ions from the given samples	**Analyse**
CO-2	Obtain expertise in preparing stock solutions and volumetric methods	**Understand**
CO-3	Identify cationic/anionic species with specific group separation procedures	**Apply**
CO-4	Develop semi-micro qualitative analytical skills	**Skill**
CO-5	Analyze and articulate simple methods of Qualitative Analysis	**Skill**

Volumetric Analysis:

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
2. Estimation of oxalic acid by titrating it with $KMnO_4$.
3. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.
4. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using an internal indicator.
5. Estimation of Cu (II) ions iodometrically using $Na_2S_2O_3$.
6. Estimation of (i) Mg^{2+} or (ii) Zn^{2+} by complexometric titrations using EDTA.
7. Estimation of total hardness of a given sample of water by complexometric titration.

Qualitative Analysis:

Semi-micro qualitative analysis - not more than four ionic species (a mixture containing two cations and two anions of which one will be an interfering ion) out of the following (excluding insoluble salts):

Cations: NH_4^+, Pb^{2+}, Ag^+, Bi^{3+}, Cu^{2+}, Cd^{2+}, Sn^{2+}, Fe^{3+}, Al^{3+}, Co^{2+}, Cr^{3+}, Ni^{2+}, Mn^{2+}, Zn^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, K^+

Anions: CO_3^{2-}, S^{2-}, SO_2^{-}, $S_2O_3^{2-}$, NO_3^-, CH_3COO^-, Cl^-, Br^-, I^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, BO_3^{3-}, $C_2O_4^{2}$, F^- (Spot tests should be carried out wherever feasible)

Reference Books

1. In-house manual prepared by Department of Chemistry, CUTN, Thiruvarur.
2. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012. Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
3. G. H. Jeffery, J. Bassett, J. Mendham, and R. C. Denney, Vogel's quantitative chemical analysis, 5th edition, Longman Scientific and Technical, 1989.
4. J. Mendham, J. C. Denney, J. D. Barnesand, M. J. K. Thomas: Vogel's Prescribed book of qualitative chemical analysis, 6th Edition, Prentice Hall, 2000.
5. M. Hein, J. N. Peisen and R. L. Miner, Foundations of College Chemistry in the Laboratory, John Wiley and Sons, 2011.
6. J. D. Woollins, Inorganic experiments, 3rd Edition, Wiley-VCH Verlag GmbH Co., 2012.
7. Ghoshal, Mahapatra and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	3
2	1	1	1	1	3
3	3	2	3	1	2
4	2	1	2	1	3
5	2	1	2	1	2

Semester: IV **Course Type: Theory** **Course Code: CHE1041**
Credit: 3 **Course Title: Organic Chemistry-I**

Course Outcomes		Level
CO-1	Identify the type of isomerism existing in organic compounds	**Apply**
CO-2	Describe the structure and chemical properties of aromatic hydrocarbons	**Understand**
CO-3	Predict the mechanism of nucleophilic substitution and elimination reactions of alkyl halides.	**Understand**
CO-4	Demonstrate the mechanism and synthetic applications of some important name reactions of alcohols and phenols	**Remember**
CO-5	Know the chemistry of carbonyl compounds and their interconversions	**Remember**

Unit-I Stereochemistry

Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula to Newman, Sawhorse and Fischer representations. Concept of chirality (up to two carbon atoms). Principles of symmetry – symmetry elements (Cn, Ci and Sn) - asymmetry – isomerism – constitutional isomers – stereoisomers. Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and meso compounds. *Threo* and *erythro*; D and L; *cis – trans* nomenclature; CIP Rules: R/ S (for up to 2 chiral carbon atoms) and E / Z Nomenclature (for up to two C=C systems).

Unit-II Aromatic hydrocarbons

Aromaticity: Benzenoids and Hückel's rule. Benzene: Structure of benzene, Preparation from phenol, from acetylene, from benzene sulphonic acid. Reactions: Aromatic Electrophilic substitution: nitration, halogenation and sulfonation. Friedel-Craft's reaction (alkylation and acylation). Side chain oxidation of alkyl benzenes. Polycyclic aromatic hydrocarbons: structure, preparation, and aromaticity of naphthalene, phenanthrene and anthracene.

Unit-III Alkyl and aryl halides

Alkyl halides: Nomenclature of alkyl halides. Preparation: from alkenes and alcohols. Nucleophilic substitution reactions (S_N1, S_N2 and S_Ni), stereochemical aspects. Reactions: hydrolysis, Williamson ether synthesis, nitrite and nitro formation. Aryl halides: Preparation, properties and reactions. Introduction to electrophilic and nucleophilic aromatic substitution reaction mechanisms

Unit-IV Alcohols and Phenols

Alcohols: Preparation using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters. Reactions: with sodium, HX (Lucas test), esterification, oxidation reaction.

Phenols: Preparation: from Cumene and diazonium salts. Reactions: Electrophilic substitution: Nitration, halogenation and sulfonation. Reimer-Tiemann reaction, Gattermann-Koch reaction, Houben–Hoesch Condensation, Schotten–Baumann reaction. Di- and Tri-hydric phenols: Preparation of catechol and phloroglucinol.

Unit-V Chemistry of Carbonyl compounds

Aldehydes and Ketones: Preparation from acid chlorides, nitriles. Reactions with HCN, ROH, NH_2-G derivatives, iodoform test, Aldol Condensation, Cannizzaro's reaction, Clemmensen reduction, Wolff Kishner reduction. Oxidation reactions of carbonyl compounds.

Carboxylic acids: Nomenclature and classification of aliphatic and aromatic carboxylic acids. Mono, di- and unsaturated carboxylic acids: preparation and reactions. Carboxylic acid derivatives: preparation and reactions of acid chlorides, anhydrides, amides and esters.

Reference Books:

1. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
2. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford Univ. Press, 2014.
3. Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8nd Ed., Wiley Publications, 2019
4. Graham Solomons, T. W. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
5. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
6. I. L. Finar, Organic Chemistry, Vol I, 6th Ed, Pearson Education, 2002.
7. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Ed., Orient Longman, New Delhi, 1988.
8. Francis A. Carey and Richard J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, 5th Ed. 2007
9. Robert B. Grossman, The Art of Writing Reasonable Organic Reaction Mechanisms, 2nd Ed, Springer, 2003
10. L. G. Wade, Organic Chemistry, 6th Ed. Pearson, 2006
11. Francis A. Carey, Robert M. Giuliano, Organic Chemistry, 8th Ed. 2008
12. Peter Vollhardt, Neil Schore, Organic Chemistry-Structure and Function, 6th Ed. W. H. Freeman and Company, 2011
13. Thomas H. Lowry, Kathleen Schueller Richardson, Mechanism and Theory in Organic Chemistry, Harper and Row Publishers
14. Edwin S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Publications, 1959

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	1	1	3	1
2	1	1	3	2	2
3	2	1	2	2	1
4	1	1	3	2	1
5	2	1	2	2	1

Semester: IV **Course Type: Practical** **Course Code: CHE1042**
Credit: 2 **Course Title: Organic Chemistry Laboratory-I**

Course Outcomes		Level
CO-1	Understand the chemistry of functionalized organic compounds	**Understand**
CO-2	Explain the procedure for the systematic analysis of oxygen and nitrogen based functional groups	**Apply**
CO-3	Examine qualitative analysis of unknown organic compounds systematically	**Analyze**
CO-4	Analyze and articulate simple methods of preparation of functional group derivatives	**Apply**
CO-5	Determine the chemical nature and the purity of the prepared derivatives by simple testing	**Evaluate**

Qualitative Analysis of Organic Compounds

(a) Identification of acidic, basic, phenolic and neutral organic substances.
(b) Test for saturation and unsaturation.
(c) Test for aliphatic and aromatic nature of substances.
(d) Detection of nitrogen, sulfur and halogens.
(e) Identification of functional groups:

(i) Carboxylic acids (ii) Phenols (iii) Aldehydes (iv) Ketones (v) Esters
(vi) Carbohydrates (vii) Amines (viii) Amides (ix) Nitro (x) Halogen

Preparation and determination of melting or boiling points of derivatives for the functional groups

(a) Reduction of nitrobenzene (b) Oxidation of benzaldehyde
(c) Esterification of salicylic acid (d) Acetylation of aniline
(e) Hydrolysis of methyl salicylate (f) Nitration of phenol

Reference Books:

1. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Textbook of Practical Organic Chemistry, Prentice-Hall, 5th Ed, 1996.
2. F. G. Mann, B. C. Saunders, Practical Organic Chemistry, 4th Ed, Pearson Education India, 2009.
3. B. Haynes, Qualitative Organic Analysis, Pearson Education, 2011.
4. P. B. Cranwell, L. M. Harwood, C. J. Moody, Experimental Organic Chemistry, 3rd Ed, Wiley-Blackwell, 2017.
5. V. K. Ahluwalia, R. Aggarwal, Comprehensive Practical Organic Chemistry, Universities Press, 2004.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	3	2	2	3
2	1	3	2	2	3
3	2	3	2	2	3
4	2	3	2	2	3
5	1	3	2	2	3

Semester: V **Course Type: Theory** **Course Code: CHE1051**
Credit: 4 **Course Title: Analytical Methods in Chemistry**

Course Outcomes		Level
CO-1	Analyse the accuracy and precision of statistical data	**Apply**
CO-2	Introduce various thermal and electroanalytical methods	**Knowledge**
CO-3	Understand the methodologies of analytical spectroscopy and separation techniques	**Understand**
CO-4	Elucidate the analytical applicability of chromatography and spectroscopy in real samples (water quality, waste water treatment, etc.)	**Skill**

Unit-1 Error Analysis

Errors, accuracy and precision, methods of their expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals, Correlation & regression, correlation coefficient and linear regression.

Unit-II Gravimetric & Electroanalytical Methods

Gravimetric Analysis–Principles, methods–requirements, Precipitation-theories of precipitation. Types of precipitation – co precipitation, post precipitation and precipitation from homogeneous solution-digestion, filtration and washing, drying and ignition. Inorganic and organic precipitating agents.

Electroanalytical Methods-Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

Unit-III Spectrophotometry

Optical methods of analysis: Origin of EMR spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.

UV-Visible Spectrometry: Basic principles of instrumentation (Choice of source, monochromator and detector) for single and double beam instruments. Applications: Estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Woodward–Fieser Rules (enones only), Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method.

Infrared Spectrometry: Basic principles & sampling techniques. Factors influencing vibrational frequencies. Structural illustration through interpretation of data, Effect and importance of isotope substitution.

Unit-IV Flame and Thermal Analysis

Flame Atomic Absorption and Emission Spectrometry: Basic principles Choice of flame and Burner designs. Techniques of atomization and sample introduction; Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water samples.

Thermal methods of analysis: Theory of thermogravimetry (TG), Differential Thermal Analysis (DTA), Differential Scanning Calorimeter (DSC) -Basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture.

Unit-V Separation Techniques

Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation. Technique of extraction: batch, continuous and counter current extractions. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and non-aqueous media.

Chromatography: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition &ion exchange. Development of chromatograms: frontal, elution and displacement methods. Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

Reference Books:

1. G.H. Jeffery, J. Bassett, J. Mendham, & R.C. Denney, Vogel's Textbook of Quantitative Chemical Analysis, 5thEd., John Wiley & Sons, 1989.
2. H.H. Willard, L.L. Merritt, J. Dean, & F.A. Settoe, Instrumental Methods of Analysis, 7th Edn. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988.
3. G. D. Christian, P. K. Dasgupta, K. A. Schug, Analytical Chemistry, 7th Ed., John Wiley& Sons, New York, 2004.
4. D. C. Harris, Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2004.
5. S.M. Khopkar, Basic Concepts of Analytical Chemistry,3rd Edn., New Age, International Publisher, 2017.
6. D.A. Skoog, F.J. Holler & T.A. Nieman, Principles of Instrumental Analysis, 6thEdn, Cengage Learning India Ed.1998.
7. O. Mikes, Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979.
8. R.V. Ditts, Analytical Chemistry; Methods of Separation, New York van Nostrand, 1974

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	3	1	2	1	3
2	2	1	2	1	3
3	3	2	3	1	3
4	2	1	3	1	3

Semester: V **Course Type: Theory** **Course Code: CHE1052**
Credit: 4 **Course Title: Inorganic Chemistry-II**

Course Outcomes		Level
CO-1	Understand the basics of p block elements	**Understand**
CO-2	The students acquire knowledge of crystal structures and crystal defects	**Remember**
CO-3	The students know about the composition and stability of the nucleus and types of nuclear reactions	**Understand**
CO-4	Grasp chemistry of p-block elements (B, C, N, O and halogen groups) & noble gases	**Remember**
CO-5	predict the reaction and balancing the reaction of p-block elements	**Understand**

UNIT-I p-Block elements - Boron and Carbon family

General characteristics of elements of Group III A - Extraction of Boron - Physical and chemical properties of Boron - compounds of boron - Borax, Boric acid, Diborane, Boron nitride - Extraction of Al - Physical and Chemical properties - uses - compounds of aluminium - Al_2O_3, $AlCl_3$, alums - Alloys of aluminium. General characteristics of elements of Group IV A - Allotropic forms of carbon - Chemistry of charcoal - chemistry of oxides of carbon-preparation of Silicon - Physical and chemical properties of Si - Uses - Oxides of silicon - structures of silicates. Chemistry of silicones - Manufacture of glass - types of glasses - ceramics - extraction of lead - physical and chemical properties - Uses - lead pigments.

UNIT-II p-Block elements - Nitrogen and Oxygen family

General characteristics of elements of V A Group - Preparation of nitrogen - Physical and chemical properties of nitrogen - uses - Chemistry of some compounds of nitrogen - hydrazine, hydroxylamine, hydrazoic acid, nitric acid - nitrogen cycle. Preparation of phosphorus - Physical and chemical properties of phosphorus - uses - chemistry of PH_3, PCl_3, PCl_5, $POCl_3$, P_2O_5 and oxyacids of phosphorous - fertilizers - Oxides of nitrogen and Phosphorous - oxoacids of nitrogen and phosphorus. Anomalous behavior of oxygen - Structure and allotropy of elements, ozone, oxides - peroxides, suboxides, basic oxides, amphoteric oxides, acidic oxides, neutral oxides - Oxides of Sulphur - oxoacids of sulphur - sulfuryl compounds - Chemistry of selenium and tellurium.

UNIT-III Halogen family and Noble gases

General characteristics of halogen with reference of electronegativity, electron affinity, oxidation states, and oxidizing power - peculiarities of fluorine, Hydrides, oxides and oxo acids of halogens Interhalogen compounds - polyhalide ions - pseudohalogens - preparation, properties and structure of interhalogen compounds Inert gases - position in the periodic table - isolation from atmosphere - General characteristics - Structure and shape of xenon compounds - XeF_2, XeF_4, XeF_6, $XeOF_2$, $XeOF_4$ - uses of noble gases.

Unit-IV Solid State Chemistry

Classification of solids - amorphous and crystalline solids - Van der waals crystals - covalent crystals - Laws of crystallography - Elements of symmetry - Weiss and Miller indices - Crystal systems and Bravais lattices. Structure of ionic solids - crystal structures - Sodium chloride, Zinc blende, wurtzite, rutile, Cesium chloride, fluorite - antifluorite - Identification of simple cubic,

bcc, fcc lattices and indexing of X-ray lines. Crystal defects - Schottky and Frenkel defects - F-center.

Unit-V Nuclear Chemistry-I

Introduction - composition of nucleus and nuclear forces - nuclear stability - mass defect - binding energy - packing fraction - N/P ratio - magic numbers - nuclear models - liquid drop - Shell and collective model. Isotopes - detection and separation - deviation of atomic weights from whole numbers - isobars, isotones and isomers - Radioactive decay and equilibrium - nuclear isomerism - internal conversion. Nuclear Q-value - threshold energy - cross sections, types of reactions - fission and fusion - modes of radioactive decay - half-life period - Average life period - radioactive displacement law - radioactive series

Reference Books:

1. J. E. Huheey, E. A. Keiter, R. L. Keiterand, O. K. Medhi, Inorganic Chemistry - Principles of Structure and Reactivity, 4thedition, Pearson Education, 2006.
2. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5th edition, Oxford University Press, 2010.
3. J.D. Lee, Concise Inorganic Chemistry, Wiley, 5th edn., 2016.
4. G. L. Miessler and D. A.Tarr, Inorganic Chemistry, 3rdedition, Pearson, 2004.
5. N. N. Greenwood, and A. Earnshaw, Chemistry of the Elements, 2nd Ed, Elsevier, 2005.
6. R. M. Felder and R. W. Rousseau, Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
7. C. E. Housecraft and A. G. Sharpe, Inorganic Chemistry, 4th edition, Pearson, 2012.
8. A. G. Massey, Main Group Chemistry, 2ndedition, John and Wiley & Sons, LTD, 2000.
9. J. Arnikar, Essentials of Nuclear Chemistry, 4th edition, New Age International Publishers Ltd., New Delhi, 1995.
10. W. D. Lovel, D. J. Morrissey and G. T. Seaborg, Modern Nuclear Chemistry, Wiley-VCH Verlag GmbH Co. KGaA, 2006.
11. Glasstone, Source Book on Atomic Energy, 3rd edition, Affiliated East West Press, 1979.
12. B. E. Douglas, D.H. McDaniel, &J.J. Alexander, Concepts and Models in Inorganic Chemistry, John Wiley & Sons. 2010.
13. G. Wulfsberg, Inorganic Chemistry, Viva Books Pvt. Ltd. 2014.
14. F. A. Cotton, G. Wilkinson, C. A. Murilloand, M. Bochmann, Advanced Inorganic Chemistry, 6thEdition, John Wiley & Sons, 2008.
15. N. N. Greenwoodand A. Earnshaw, Chemistry of the Elements, 2nd Ed, Elsevier, 2005.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	3
2	1	1	1	1	3
3	3	2	3	1	3
4	2	1	2	1	3
5	2	1	2	1	2

Semester: V **Course Type: Theory** **Course Code: CHE1053**
Credit: 4 **Course Title: Organic Chemistry-II**

Course Outcomes		Level
CO-1	Describe the physical and chemical properties amines and their derivatives	**Understand**
CO-2	Learn about the structure, preparation and properties of heterocyclic compounds	**Remember**
CO-3	Deduce the mechanistic and reaction pathways of nucleophilic addition reactions	**Understand**
CO-4	Predict the mechanism, orientation and factors influencing elimination reactions.	**Apply**
CO-5	Demonstrate the mechanism of organic transformations based on carbanion intermediates	**Analyze**

Unit-I Amines and Diazonium Salts

Amino compounds – nomenclature and classification. Preparation from alkyl halides, Gabriel's phthalimide synthesis. Reactions: Carbylamine reaction, Hofmann Bromamide reaction, diazotization – comparison of aliphatic and aromatic amines. Reductive amination of aldehydic and ketonic compounds. Amidine, azide, azo, diazoalkanes, cyanates, nitrile, nitrite, oxime, carbamate ester, nitro compounds and diazonium salts – preparation and reactions.

Unit-II Heterocyclic compounds-I

Nomenclature of heterocyclic compounds with one and two heteroatoms (O, N and S). Molecular orbital structure and aromatic characteristics of pyrrole, furan, thiophene and pyridine; Synthetic protocols and reactivity with particular focus on electrophilic substitution. Nucleophilic substitution of pyridine; comparison of basicity of pyridine, piperidine and pyrrole. Skraup synthesis of quinoline, Napieralski synthesis of isoquinoline. Heterocyclic dyes: preparation and uses of – fluorescein, Indigo and sulfur black dyes.

Unit-III Addition Reactions

Hydrogenation of alkene: syn and anti-addition. Electrophilic addition to alkenes: Markovnikov's Rule – HX, H_2O, H_2SO_4, halogen, oxymercuration, hydroboration and oxidation & oxidation of alkenes to diols. Conjugate addition to alkenes. Nucleophilic addition reaction to carbonyl group, reactivity of aldehydes and ketones and explanation of molecular orbitals. Addition of oxygen, nitrogen, sulfur and carbon-based nucleophiles to carbonyls. Reactions with ylides.

Unit-IV Elimination Reactions and Carbanions as nucleophiles

Elimination reactions: E1, E2 and E1cB reactions – mechanisms – factors influencing elimination - stereochemistry. Zaitsev and Hofmann rule – dehydrohalogenation, dehydration of alcohols, quaternary ammonium salts. Pyrolytic elimination

Carbanions: Acidity of hydrocarbons – carbanion character of organometallic compounds – carbanions stabilized by functional groups – enols, enamines and imines – carbanions as nucleophiles in S_N2 reactions. Synthetic applications of enamines.

Unit-V Organic transformations based on reactive species

Dicarboxylic acids, dicarbonyls and diesters. Acidity of α-hydrogens, active methylene - alkylation of diethyl malonate and ethyl acetoacetate. Synthesis of substituted dicarboxylic acids, α,β-unsaturated acids, diketones and α,β-unsaturated ketones using diethyl malonate and ethyl acetoacetate. Claisen condensation, Knoevenagel condensation, Diekmann condensation

Carbenes and Nitrenes: Generation, classifications, stability and reactivities.

Reference Books:

1. Raj K. Bansal, Heterocyclic Chemistry, 4th Ed., Anshan Limited, 2008.
2. Alan R. Katritzky, Christopher A. Ramsden, John A. Joule, Viktor V. Zhdankin Handbook of Heterocyclic Chemistry, Elsevier Publication, 2010.
3. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
4. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford University Press, 2014.
5. Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8nd Ed., Wiley Publications, 2019
6. Graham Solomons, T. W. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
7. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
8. I. L. Finar, Organic Chemistry, Vol I, 6th Ed, Pearson Education, 2002.
9. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Ed., Orient Longman, New Delhi, 1988.
10. Francis A. Carey and Richard J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, 5th Ed. 2007
11. Robert B. Grossman, The Art of Writing Reasonable Organic Reaction Mechanisms, 2nd Ed, Springer, 2003
12. L. G. Wade, Organic Chemistry, 6th Ed. Pearson, 2006
13. Francis A. Carey, Robert M. Giuliano, Organic Chemistry, 8th Ed. 2008
14. Peter Vollhardt, Neil Schore, Organic Chemistry-Structure and Function, 6th Ed. W. H. Freeman and Company, 2011
15. Edwin S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Publications, 1959

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	3	3	1
2	2	1	3	3	2
3	2	1	3	3	1
4	2	1	3	3	1
5	2	1	3	3	1

Semester: V **Course Type: Theory** **Course Code: CHE1054**
Credit: 4 **Course Title: Physical Chemistry-II**

Course Outcomes		Level
CO-1	Explore and understand the basic concepts/theories of the physical states of matter and Photochemistry	**Understand**
CO-2	Well-verse in the kinetic theory of gas molecules, critical phenomenon, molecular symmetry, light matter interaction etc.	**Evaluate**
CO-3	Identify the point group of molecules using group theory.	**Apply**
CO-4	Emphasis the spectrophotometric tools and analytical materials for research interest	**Create**

Unit-I Gaseous State

Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation. Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance. Collision diameter, mean free path, Transport properties of gases- determination of thermal conductivity, viscosity and diffusion coefficients- effect of temperature and pressure on coefficients (qualitative treatment only).

Real gases: Deviation & causes of real gases from ideal behaviour, compressibility factor, van der Waals equation of state – derivation and application in explaining real gas behaviour. virial form – calculation of Boyle temperature, Isotherms of real Gases-Andrews isotherms of CO_2, continuity of states. Critical phenomena, Critical constants and their calculation from van der Waals equation. Liquefaction of gases (based on Joule-Thomson effect).

Unit-II Liquid State, Liquid Crystals & Colloids

Intermolecular forces in liquids (qualitative idea only), Structure of liquids. Unusual behaviour of water. Surface tension and its determination using a Stalagmometer. surface active agents, the Parachor and chemical constitution (atomic and structural parachor), Viscosity of a liquid and determination of coefficient of viscosity using Ostwald viscometer. Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only).

Liquid Crystals: Liquid crystals thermographic behaviour. Classification and structure of nematic and cholesteric phases. Applications of liquid crystals.

Colloids: Colloids - types, preparation, Purification (dialysis, electrodialysis and ultrafilteration) and stability of colloids, gold number. Properties of colloids- kinetic, optical and electrical properties.

Unit-III Solid State

Forms of solids. unit cells, crystal systems, Bravais lattice types and identification of lattice planes. Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices. Miller indices. X–Ray diffraction by crystals, Bragg's law. Structures of NaCl, KCl and CsCl (qualitative treatment only). Defects in crystals.

Glass-Supercooled liquid. concept of conductor, semiconductor and superconductor- band theory. **Polymers**: Introduction –Classifications – Molecular weight determination methods.

Unit-IV Symmetry and Point Groups

Symmetry of molecules-symmetry elements and symmetry operations – centre of symmetry, plane of symmetry, proper and improper axes of symmetry, combination of symmetry elements,

Group multiplication table, Schoenflies symbols, Determination of point groups of simple molecules like H_2O, NH_3 and BF_3, crystallographic point groups symmetry.

Unit-V Photochemistry

Laws of photochemistry-Grothus-Draper law, Stark-Einstein law. Jablonski diagram qualitative description of fluorescence, phosphorescence, non-radiative processes (internal conversion, intersystem crossing). Quenching of fluorescence. Quantum yield, examples of low and high quantum yields, photochemical reactions (decomposition of HBr, isomerisation of maleic acid to fumaric acid), photosensitised reactions (photosynthesis, isomerisation of 2-butene), chemiluminescence, bioluminescence.

Reference Books:

1. K. L. Kapoor, A Textbook of Physical chemistry, Volumes 1, 6thEdn. Macmillan India Ltd, 2020.
2. B.R. Puri, L.R. Sharma and M.S. Pathania, Principles of Physical Chemistry, 48thEdn. Vishal Publishing Co, 2019.
3. P. Atkins and J. Paula, The elements of Physical chemistry, 7thEdn., Oxford University Press, 2016.
4. D. A. McQuarrie, J. D. Simon, Physical Chemistry – A molecular Approach, Viva Books Pvt. Ltd, 1997.
5. K. J. Laidler and J. M. Meiser, Physical Chemistry 3rd Edition, Houghton Mifflin Comp., New York, International Edition, 1999.
6. K. K. Sharma, L R Sharma, A textbook of Physical Chemistry, 6thEdn., Vikas Publishing house, 2016.
7. I. N. Levine, Physical Chemistry, 6th Edn. Tata Mc Graw Hill, 2011.
8. G. Raj, Photochemistry, 6th Edn, Goel Publishing House, 2014.
9. K.K. Rohatgi and K.K. Mukherjee, Fundamentals of Photochemistry, 4thEdn., New Age International (P) Ltd, 2021.
10. V. Ramakrishnan and M. S. Gopinathan, Group Theory in chemistry, Vishal Publication, 1986.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	3	1	2	1	1
2	3	1	2	1	1
3	3	1	2	1	1
4	3	1	3	2	2

Semester: V **Course Type: Practical** **Course Code: CHE1055**
Credit: 2 **Course Title: Inorganic Chemistry Laboratory-II**

Course Outcomes		Level
CO-1	Estimate inorganic compounds from a mixture	**Apply**
CO-2	Value volumetric and gravimetric procedures	**Evaluate**
CO-3	Apply UV-Vis spectroscopy to estimate concentration of an ion in given solution	**Apply**
CO-4	Handle spectrophotometric tools, analytical materials, etc. of specific interest	**Skill**
CO-5	Application of Job's method to analyse the complexes	**Analyze**

1. Estimation of inorganic compounds in a mixture by Volumetric and Gravimetric analysis.
A mixture of solution(s) should be given for estimation (Any three mixtures)
   (i) Cu (V) and Ni (G)
   (ii) Fe (V) and Zn (G)
   (iii) Fe (V) and Ni (G)
   (iv) Zn (V) and Cu (G)

2. Draw a calibration curve (absorbance at λ_{max} vs. concentration) for various concentrations of a given coloured compound ($KMnO_4$/ $CuSO_4$) and estimate the concentration of the same in a given solution.

3. Determine the composition of the Fe^{3+}-salicylic acid complex solution by Job's method.

Reference Books:

1. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
2. Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
3. In-house manual prepared by Department of Chemistry, CUTN, Thiruvarur.
4. M. Ghoshal and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.
5. V. Venkateswaran, R. Veerasamy and A. R. Kulandaivelu, Basic principles of Practical Chemistry, 2nd edition, New Delhi, Sultan Chand & sons, 1997.
6. M. Hein, J. N. Peisen and R. L.Miner, Foundations of College Chemistry in the Laboratory, John Wiley and Sons, 2011.
7. Amita Dua, Navneet Manav, Practical Inorganic Chemistry, Manakin Press, New Delhi, 2017.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	2	2	1	3
2	1	2	1	1	3
3	2	3	3	1	3
4	2	3	2	1	3
5	2	2	3	3	2

Semester: V **Course Type: Practical** **Course Code: CHE1056**
Credit: 2 **Course Title: Organic Chemistry Laboratory-II**

Course Outcomes		Level
CO-1	Develop various analytical skills and techniques necessary for the analysis of biological molecules.	**Analyze**
CO-2	Discuss purification of organic compounds by the Column chromatography	**Apply**
CO-3	Appraise and utilize the analytical knowledge to understand various biological processes	**Analyze**
CO-3	Perform synthesis and characterization of the organic compounds	**Analyze**
CO-4	Explain the mechanism of chemical reactions involved in the preparations of organic compounds	**Evaluate**

Qualitative analysis by separation techniques
Column chromatography of leaf and flower extract.
TLC – Separation of triglycerides.
Paper Chromatography – Separation of amino acids.
Tests for carbohydrates and amino acids.

Preparation, purification of organic compounds and discussions on mechanisms
Preparation of *p*-bromoacetanilide from acetanilide
Preparation of picric acid from phenol
Preparation of *p*-nitroacetanilide from acetanilide
Preparation of aromatic acid from an ester/amide
Benzoylation of amine/phenols
Acetylation of amine/phenols

Reference Books

1. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Textbook of Practical Organic Chemistry, Prentice-Hall, 5th Ed, 1996.
2. F. G. Mann, B. C. Saunders, Practical Organic Chemistry, 4th Ed, Pearson Education India, 2009.
3. B. Haynes, Qualitative Organic Analysis, Pearson Education, 2011.
4. P. B. Cranwell, L. M. Harwood, C. J. Moody, Experimental Organic Chemistry, 3rd Ed,
5. Wiley-Blackwell, 2017.V. K. Ahluwalia, R. Aggarwal, Comprehensive Practical Organic Chemistry, Universities Press, 2004.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	3	3	3
2	2	3	3	3	3
3	2	3	3	3	3
4	2	3	3	3	3
5	2	3	3	3	3

Semester: V **Course Type: Practical** **Course Code: CHE1057**
Credit: 2 **Course Title: Physical Chemistry Laboratory-II**

Course Outcomes		Level
CO-1	Well verse with the basic laboratory instruments	**Analyze**
CO-2	Present the experimental data in a scientific manner	**Evaluate**
CO-3	Apply fundamental concepts and evaluate physical parameters of solutions	**Apply**
CO-4	Correlate physical parameters with the chemical properties of analyte	**Remember**

Surface tension measurement (use of organic solvents excluded)

(a) Determination of the surface tension of a liquid or a dilute solution using a Stalagmometer.

(b) Study of the variation of surface tension of a detergent solution with concentration.

Viscosity measurement (use of organic solvents excluded).

(a) Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald's viscometer.

(b) Study of the variation of viscosity of an aqueous solution with concentration of solute.

Chemical Kinetics

(a) Initial rate method: Iodide-persulphate reaction

(b) Integrated rate method:

(i) Acid hydrolysis of methyl acetate with hydrochloric acid.

(ii) Saponification of ethyl acetate.

(iii) Compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of methyl acetate.

Phase equilibria

(a) Study of the variation of mutual solubility temperature with concentration for the phenol water system and determination of the critical solubility temperature.

Potentiometry: Potassium dichromate vs. Mohr's salt

Conductance

(a) Determination of cell constant

(b) Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

Reference Books:

1. J.B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, **2001.**
2. G.W. Garland, J.W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8th Edn. McGraw Hill, **2009.**
3. B. Viswanathan, Practical Physical chemistry, Viva Pub., **2005.**
4. A.M. James, F.E. Prichard, Practical Physical Chemistry Paperback, **1974.**
5. A. Dau, Practical Physical Chemistry, Manakin press, **2017.**

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	2	2	3
2	2	3	2	2	3
3	2	2	3	2	3
4	2	3	3	2	3

Semester: VI **Course Type: Theory** **Course Code: CHE1061**
Credit: 4 **Course Title: Inorganic Chemistry-III**

Course Outcomes		Level
CO-1	Obtain basic knowledge in the transition and inner transition elements	**Remember**
CO-2	Understand about the various basic concepts of coordination complexes	**Understand**
CO-3	Know the reaction mechanisms in coordination complexes	**Remember**
CO-4	Get the basics in organometallic chemistry and its applications in catalysis	**Remember**
CO-5	Understand the principles in bioinorganic chemistry and its role in biology	**Understand**

UNIT-I d- and f- Block Elements

Chemistry of transition elements - electronic configuration - group study of titanium, vanadium, chromium, manganese and iron metals - comparative study of zinc group metals - Important uses of transition metals and their alloys. Horizontal comparison with Fe, Co, Ni groups - toxicity of Cd and Hg - oxides, mixed oxides, halides, and oxohalides of transition metals - synthesis and reactivity of vanadates, chromates, dichromate, molybdates, tungstates, tungsten bronzes, manganate, permanganate - polycations - Interstitial compounds - nitrides, carbides, hydrides, borides of Ti, V, Cr, W and their industrial uses. General characteristics of f-block elements - comparative account of lanthanides and actinides - lanthanide series - separation by ion exchange and solvent extraction methods - lanthanide contraction - actinide series - separation of actinides - oxidation states and general properties - Uranium - occurrence and metallurgy - chemical properties of oxides, hydrides and halides.

UNIT-II Coordination Chemistry I

IUPAC nomenclature - theories of coordination compounds - Werner, Sidgwick, valence bond, Crystal Field theory. Crystal field splitting in octahedral, tetrahedral and square planar fields - factors influencing the magnitude of crystal field splitting - CFSE in weak and strong fields calculations; pairing energy. Jahn-Teller distortion. Magnetism and Colour: Orbital and spin magnetic moments, spin only moments of dn ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment.

UNIT-III Coordination Chemistry II

Stability of complexes -factors affecting the stability of complexes - Stability constants of coordination compounds and their importance in inorganic analysis. Kinetic versus thermodynamic stability. Experimental determination of stability constant and composition of complexes. Isomerism, reactivity and stability: Determination of configuration of cis- and trans-isomers by chemical methods. Labile and inert complexes, substitution reaction on square planar complexes, trans effect– theories (example and applications). Reaction mechanism - substitution reactions in octahedral complexes – Acid hydrolysis: S_N1 and S_N2 mechanisms.

UNIT-IV: Bioinorganic Chemistry

A brief introduction to bioinorganic chemistry - occurrence and availability of inorganic elements in biological systems. Metal ions in biology and their vital role in the active site, structure and functions of Metalloproteins and enzymes. Structures and characteristic features of

haemoglobin and myoglobin - Vitamin B_{12}. Biological functions of haemoglobin and myoglobin, cytochromes and ferredoxins, carbonate and bicarbonate buffering system and carbonic anhydrase. Introduction to biological nitrogen fixation and photosynthesis.

UNIT-V Organometallic Chemistry

Origin of organometallic compounds - Introduction - Nomenclature of organometallic compounds- 18- electron rule - structures and bonding - metal carbonyls- mono and polynuclear carbonyls of Ni, Fe, Cr, Co and Mn - bridging and terminal carbonyls -synthesis and structure - nitrosyl compounds. Transition metal alkyls, carbenes, carbynes, and metallocenes. Catalysis and industrial applications -Wilkinson's catalyst and alkene hydrogenation, hydroformylation, Monsanto acetic acid process, Ziegler - Natta catalyst and polymerization of olefins.

Reference Books:

1. J. E. Huheey, E. A. Keiter, R. L. Keiter, and O. K. Medhi, Inorganic Chemistry - Principles of Structure and Reactivity, 4th edition, Pearson Education, 2006.
2. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5thedition, Oxford University Press, 2010.
3. J. D. Lee, Concise Inorganic Chemistry, 5th edition, Wiley, 2016.
4. S. J. Lippard, J. M. Berg, Principles of Bioinorganic Chemistry, Panima Publishing Company, New Delhi, 1997.
5. W. Kaim and B. Schewederski, Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, John Wiley & Sons, New York, USA, 2013.
6. Didier Astruc, Organometallic Chemistry and Catalysis, Springer, 2007.
7. B. D. Gupta and A.J. Elias, Basic Organometallic Chemistry: Concepts, Syntheses, and Applications of Transition Metals, 1st edition, Universities Press, CRC Press, 2010.
8. R. H. Crabtree, Organometallic Chemistry of Transition Metals, Wiley, New York, 1988.
9. C. E. Housecraft and A.G. Sharpe, Inorganic Chemistry, 4thedition, Pearson, 2012.
10. G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3rd edition, Pearson, 2004.
11. G.Chatwal, M.S.Yadu, Coordination Chemistry, 1st Ed, HimalayaPublishingHouse, 1992.
12. M. C. Day Jr, J. Selbin, Theoretical Inorganic Chemistry, Literary Licensing, LLC, 2012.
13. F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, Advanced Inorganic Chemistry, 6th edition, John Wiley & Sons, 2008.
14. B. Douglas, D. McDaniel and J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd edition, John Wiley & Sons, 2010.
15. H. E. Boyer, and T. L. Gall, Metals Handbook, Desk edition, 1984.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	3	3
2	1	1	1	3	3
3	3	2	3	3	3
4	2	1	2	2	3
5	2	2	2	3	2

Semester: VI **Course Type: Theory** **Course Code: CHE1062**
Credit: 4 **Course Title: Organic Chemistry-III**

Course Outcomes		Level
CO-1	Target synthesis of various molecules by various types of rearrangements	**Understand**
CO-2	Learn the basic biological concepts of biomolecules and natural products	**Remember**
CO-3	Articulate the functions of proteins and nucleic acids	**Understand**
CO-4	Construct the structure of new alkaloids and terpenoids from different methods	**Apply**
CO-5	Elucidate the structure determination of biomolecules and natural products	**Evaluate**

Unit-I Molecular rearrangements

Introduction, Classification – electrophilic, nucleophilic and free radical rearrangements, Nucleophilic: Rearrangements to electron deficient carbon - Pinacol-pinacolone, Wagner–Meerwin, Tiffenev-Demjanov, Benzil–Benzilic Acid, Rearrangements to electron deficient nitrogen - Hofmann, Schmidt, Lossen, Curtius, Beckmann, Rearrangements to electron deficient oxygen - Baeyer–Villiger, Cumene Hydroperoxide. Electrophilic: Wittig, Stevens and Fries rearrangement and Baker Venkatraman rearrangement.

Unit-II Carbohydrates

Classification, and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, anomerisation, epimerization, ascending and descending in monosaccharides. Structure of disacharrides (sucrose, cellobiose, maltose, lactose) and polysacharrides (starch and cellulose) excluding their structure elucidation.

Unit-III Amino Acids, Proteins and nucleic acids

Amino Acids: Preparation - Strecker synthesis, Gabriel's phthalimide synthesis. Zwitterion & Isoelectric point, Electrophoresis. Reactions: ester of –COOH group, acetylation of $–NH_2$ group, complexation.

Proteins: Primary, Secondary, Tertiary and Quaternary Structure of proteins, Edman Degradation and thiohydantoin method. Peptide linkages – Synthesis of simple dipeptides

Nucleic acids: Introduction, purine and pyrimidine bases, structure of nucleosides, nucleotides and polynucleotides, RNA and DNA (an elementary idea about their structure) RNA -types and functions, DNA replication, genetic code and biosynthesis of proteins.

Unit-IV Alkaloids and Terpenoids

Alkaloids: Occurrence, importance, classification, Isolation, General methods of determining structures including Hoffmann's exhaustive methylation, Structural elucidation and synthesis of coniine, nicotine, quinine, piperine and morphine.

Terpenoids: Occurrence, importance, classification, Isolation, Isoprene rule, Structural elucidation and synthesis of citral, geraniol, α-terpineol, limonene, menthol and camphor

Unit-V Vitamins and Pigments

Vitamins: Classification, properties, physiological functions, structural elucidation and synthesis of vitamins A (Retinol), B1, B2 (Riboflavin), B6, B12, vitamin C (Ascorbic acid).

Natural pigments: Occurrence, extraction, classification, chemical characterization and functions of anthocyanins, flavonoids, xanthophylls and porphyrins. Chemistry and structure of cyanins, flavones, flavonol, quercetin. Structure and synthesis of porphyrin skeleton, haemin and chlorophyll.

Reference books

1. Jie Jack Li, Name Reactions: A Collection of Detailed Mechanisms and Synthetic Applications, 5th Ed, Springer, 2014
2. Christian M. Rojas, Molecular Rearrangements in Organic Synthesis, John Wiley & Sons, Inc, 2015
3. I. L. Finar, Organic Chemistry, Vol II, 6th Ed, Pearson Education, 2002.
4. G.P. Talwar, L.M. Srivatsava and K.D. Moudgil, Textbook of Biochemistry and Human Biology, Prentice-Hall of India Limited, New Delhi 2003
5. J.L. Jain, Biochemistry, S. Chand and Sons, New Delhi 2004.
6. M.K. Jain, S.C. Sharma, Modern Organic Chemistry, Vishal publishing Co. 2014, 4th Ed.
7. A. Lehninger, D. L. Nelson, M. Cox and M. M. Cox, Principles of Biochemistry, MPS Publishers, New York, 2009.
8. A.V.S.S. Rama Rao, Text Book of Biochemistry, U B S Publishers, 2008, 9th Ed.
9. Gurdeep R. Chatwal, Chemistry of Natural products, Himalaya publishing House Pvt. Ltd, Mumbai, 2018, Vol I & II.
10. O.P. Agarwal, Chemistry of Natural products, Goel publishing Co, New Delhi 2001, Vol I & II.
11. U. Satyanarayana and U. Chakrapani, Biochemistry, Elsevier, 2019, 5th Ed.
12. Christian M. Rojas, Molecular Rearrangements in Organic Synthesis, John Wiley & Sons, Inc, 2015
13. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	3	3	1
2	2	1	3	3	1
3	2	1	3	3	1
4	2	1	3	3	1
5	2	1	3	3	1

Semester: VI **Course Type: Theory** **Course Code: CHE1063**
Credit: 4 **Course Title: Physical Chemistry-III**

Course Outcomes		Level
CO-1	Analyse the physical significance of wave function, its application in molecular modelling and fundamentals in spectroscopy	**Analyze**
CO-2	Evaluate the molecular physical phenomena as a function of spectral parameters	**Evaluate**
CO-3	Apply various operators used in quantum mechanics	**Apply**
CO-4	Emphasis different theoretical aspects of spectroscopic techniques	**Understand**

Unit-I Quantum Chemistry-I

The success of quantum theory and failure of the classical mechanics-experimental foundation of quantum mechanics-black body radiation-photoelectric effect and Compton effect. Formulation of quantum mechanics-the wave nature of sub-atomic particles-wave particle dualism-Heisenberg's uncertainty principle- postulates of quantum mechanics, operators - orthogonality and normalization theorem, Schrodinger wave equation derivation (Time dependent), eigen values and eigen functions, the significance of wave function,

Unit-II Application of Schrodinger Equation

Particle-in-a-box (1D, 2D and 3D boxes), Quantum Mechanical tunnelling, Simple harmonic oscillator, Particle in a ring. Rigid rotator - model of rotation of diatomic molecule. Schrödinger equation, transformation to spherical polar coordinates. Separation of variables. Spherical harmonics. Discussion of solution. Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, and quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus.

Unit-III Optical Spectroscopy-I

Interaction of electromagnetic radiation with molecules and various types of spectra.

Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies. Fingerprint region, Fermi resonance.

Unit-IV Optical Spectroscopy-II

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.

Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyenes using free electron model.

Mossbauer spectroscopy- basic principle-isomer shift, quadrupole splitting, magnetic field effect.

Unit-V Resonance Spectroscopy

Nuclear Magnetic Resonance (NMR) spectroscopy: Nuclear magnetic spectroscopy-nuclear spin-nuclear relaxation-magnetic shielding and chemical shift, deshielding, spin-spin interactions (eg. Ethanol), Larmor precession. Introduction to ^{13}C NMR.

Electron Spin Resonance (ESR) spectroscopy: Its principle, hyperfine structure, ESR of simple radicals. Electron spin resonance spectroscopy-basic principles, hyperfine splitting, zero field splitting and Kramer's degeneracy, factors affecting 'g' value.

Reference Books:

1. R.K. Prasad, Quantum Chemistry, New Age International, 2001.
2. J. P. Lowe and K. Peterson, Quantum Chemistry,3rd Ed., Academic Press, 2006.
3. Mc Quarrie, J. D. Simon, Physical Chemistry – A molecular Approach, Viva Books1997.
4. I.N. Levine, Physical Chemistry, 7th Ed., Tata McGraw Hill, 2016.
5. G. Raj, Advanced Physical Chemistry, Goel Publishing House, 2002.
6. C. N. Banwell, & E. M. Mc Cash, Fundamentals of Molecular Spectroscopy, 4th Ed. Tata McGraw-Hill, New Delhi,2006.
7. M.C handa, Atomic structure and Chemical bonding in Molecular Spectroscopy, Tata McGraw Hill1972.
8. D. L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to spectroscopy, 3rd edn, Thomson Brooks/Cole, 2001.
9. D. N. Satyanarayana, Electronic absorption spectroscopy and related techniques, Universities Press 2001.
10. D. N. Sathyanarayana, Introduction to Magnetic Resonance Spectroscopy ESR, NMR, NQR, IK International, 2009.
11. A. Dau and C. Singh, Quantum chemistry classical to computational, Manakin press, 2017.
12. B.R. Puri, L.R. Sharma and M.S. Pathania, Principles of Physical Chemistry, 48thEdn. Vishal Publishing Co, 2019.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	3	3	1
2	2	1	3	3	1
3	2	1	2	3	1
4	2	2	3	3	1

Semester: VI **Course Type: Practical** **Course Code: CHE1064**
Credit: 2 **Course Title: Inorganic Chemistry Laboratory III**

Course Outcomes		Level
CO-1	Understand the important aspects of inorganic complex preparations	**Understand**
CO-2	Characterization of inorganic complexes using UV-Visible absorption spectroscopy	**Apply**
CO-3	Correlation of theoretical and experimental aspects of CFSE	**Apply**
CO-4	Synthesis and characterization skills of inorganic compounds	**Skills**
CO-5	Utilisation of UV-Vis absorption spectroscopy technique for studying the pH dependence of a reaction	**Skills**

Inorganic Preparations (Any six preparations)

1. Tetramminecopper(II) sulphate.
2. Potassium trioxalatoaluminate (III).
3. Tristhioureacopper(I) chloride.
4. Trisacetylacetanatoiron(III)
5. Prussian blue
6. Mohr salt
7. Silver metal nanoparticles

Spectrophotometric determinations (Any two experiments)

Determination of λ_{max} and CFSE for tetramminecopper(II) sulphate.
Determination of λ_{max} of potassium trioxalatoaluminate(III).
Study pH dependence of UV-Visible spectrum of potassium dichromate.

Reference Books:

1. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
2. J. Mendham, Vogel's Quantitative Chemical Analysis, Pearson, 2009.
3. Ghoshal, Mahapatra and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.
4. V. Venkateswaran, R. Veerasamy, A. R Kulandaivelu, Basic principles of Practical Chemistry, 2nd edition, New Delhi, Sultan Chand & sons, 2016.
5. Amita Dua, Navneet Manav, Practical Inorganic Chemistry, Manakin Press, New Delhi, 2017.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	2	1	2	2
2	1	2	2	1	2
3	2	2	3	3	3
4	2	2	2	2	3
5	3	2	2	2	3

Semester: VI **Course Type: Practical** **Course Code: CHE1065**
Credit: 2 **Course Title: Organic Chemistry Laboratory-III**

Course Outcomes		Level
CO-1	Acquire the knowledge of different mechanisms in chemical and photochemical reactions	**Understand**
CO-2	Organize organic preparations based on the various one or two step reactions	**Analyze**
CO-3	Predict synthetic aspects of organic reactions involving the rearrangement and photochemical reactions.	**Evaluate**
CO-4	Discuss isolation of natural products by the various isolation methods	**Understand**
CO-5	Test the characterization of different natural products by using various analytical and spectroscopic-methods	**Evaluate**

Preparations: Two-step preparations (any three) involving acetylation, methylation, condensation, rearrangements and photochemical reactions.

Isolation and characterization of natural products:
(a) Isolation of caffeine from tea dust (b) Isolation of casein from milk
(c) Isolation of piperine from pepper (d) Isolation of lycopene from tomato

Reference Books

1. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Textbook of Practical Organic Chemistry, Prentice-Hall, 5th Ed, 1996.
2. F. G. Mann, B. C. Saunders, Practical Organic Chemistry, 4th Ed, Pearson Education India, 2009.
3. B. Haynes, Qualitative Organic Analysis, Pearson Education, 2011.
4. P. B. Cranwell, L. M. Harwood, C. J. Moody, Experimental Organic Chemistry, 3rd Ed, Wiley-Blackwell, 2017.
5. V. K. Ahluwalia, R. Aggarwal, Comprehensive Practical Organic Chemistry, Universities Press, 2004.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	3	3	3
2	2	3	3	3	3
3	2	3	3	3	3
4	2	3	3	3	3
5	2	3	3	3	3

Semester: VI **Course Type: Practical** **Course Code: CHE1066**
Credit: 2 **Course Title: Physical Chemistry Laboratory III**

Course Outcomes		Level
CO-1	Recognize various QM software and spectroscopic (UV-VIS) methods	**Understand**
CO-2	Perform geometry optimization and spectroscopic experiments	**Analyze**
CO-3	Predict the energy gap, dipole moments and stability of organic molecules	**Apply**
CO-4	Evaluate and study the energy, concentration, structures and kinetics using various spectroscopic methods	**Evaluate**

Quantum Mechanics:

1. Optimization of Geometry and single point energy calculations of various organic molecules
2. Calculation of the energy gap between HOMO and LUMO in simple molecules and visualization of molecular orbitals.
3. Calculation of dipole moment in polar organic molecules.
4. Prediction of the stability of ortho, meta, para products of nitration of aromatic ring using DFT methods.
5. Calculation of IR stretching frequencies of groups and visualization of normal modes of vibration in organic molecules.

Spectroscopy:

1. Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions indifferent units (J molecule^{-1}, kJ mol^{-1}, cm^{-1}, eV).
2. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $K_2Cr_2O_7$.
3. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde,2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.
4. Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/$KMnO_4$/ $K_2Cr_2O_7$ in a solution of unknown concentration
5. Determine the concentrations of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture.
6. Study the kinetics of iodination of propanone in acidic medium.
7. Determine the amount of iron present in a sample using 1,10-phenathroline.
8. Determine the dissociation constant of an indicator (phenolphthalein).
9. Study the kinetics of interaction of crystal violet/ phenolphthalein with sodium hydroxide.
10. Analyse the given vibration-rotation spectrum of HCl(g)

Reference Books:

1. J. Foresman & A. Frisch, Exploring Chemistry with Electronic Structure Methods, Gaussian Inc., 2000.
2. D.C. Young, Computational Chemistry, A Practical Guide for Applying Techniques to Real World Problems, John Wiley & Sons, 2001.
3. D. Rogers, Computational Chemistry Using the PC, 3rd Edition, John Wiley & Sons, 2003.

4. A. Leach, Molecular Modelling, Principles and Applications, 2nd Edn, Longman, 2001.
5. J. M. Haile, Molecular Dynamics Simulation: Elementary Methods 2001.
6. J.B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2001.
7. B. Viswanathan and P.S. Raghavan, Practical Physical Chemistry Viva Books Pvt. Ltd., New Delhi, 2008.
8. G.W. Garland, J.W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8thEdn. McGraw Hill, 2009.
9. S. Kumar and N. Kumar, Physical Chemistry Practical, New Central Book Agency, 2012.
10. A. Dau, Practical Physical Chemistry, Manakin press, 2017.

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	1	3	2	3	3
2	1	3	2	3	3
3	1	3	2	3	3
4	1	3	2	3	3

Semester: VII **Course Type: Theory** **Course Code: CHE1071**
Credit: 4 **Course Title: Inorganic Chemistry-IV**

Course Outcomes		Level
CO-1	Gain knowledge in solid state chemistry and its applications	**Knowledge**
CO-2	Understand the chemistry of main group elements - rings, chains and clusters	**Understand**
CO-3	Grasp the basic principles and their application in coordination chemistry and reaction mechanism	**Apply**
CO4	Predict reaction mechanisms in inorganic complexes	**Analyze**
CO-5	Understand the natural and artificial radioactivity	**Understand**

Unit-I Synthesis and Reactions of Inorganic Solids

Weak Chemical forces: van der Waals forces, Hydrogen bonding, Close packing of atoms and ions HCP and BCC types of packing voids, radius ratio – derivation – its influence on structures. Lattice energy – Born-Lande equation - Kapustinski equation, Madelung constant. Structures of ionic crystals – AX and AX2 type crystal structures (NaCl, CsCl, ZnS, fluorite, antifluorite, TiO_2, SiO_2, CaC_2 etc.) – Spinel, perovskite and layer structures. Properties - Stoichiometric and non-stoichiometric defects. Band theory, n- and p- type semiconductors and superconductors and its types. Reactions - Fick's law of diffusion and its derivation, types of diffusion mechanisms, thermal decomposition of solids -Type I and Type II reactions - Synthetic methods. Energy storage materials –Li ion battery, hydrides and hydrogen storage materials – Molecular materials - fullerides– one-dimensional metals, molecular magnets, inorganic liquid crystals.

Unit-II The Chemistry of the Main Group Elements

Inorganic Rings, chains, and cages- Catenation and Heterocatenation, Heterocyclic ring system- Borazines, Phosphazines- Monomer and Polymer, S-N ring compounds, Homocyclic rings of P, S and Se. Silicate minerals and its classification based on structure. Boranes: Polyhedral skeletal electron pair theory, styx number - boron cage compounds-closo, nido, arachno, carboranes; cage compounds of S and P. Metal cluster: metal-metal bonding and reactivity of di-, tri- and polynuclear clusters, Metal cluster and metal carbonyl structure based on PSEPR theory.

Unit-III Theories and studies of coordination compounds

Crystal field theory – Splitting of d orbitals under various geometries - factors affecting splitting, CFSE, evidences for CFSE (Structural and thermodynamic effects), spectrochemical series, Jorgensen relation, site preferences, Jahn Teller distortion – Dynamic and Static J.T. effect, Jahn Teller effect and chelation, Application of CFT – Magnetic properties, spectral properties and Kinetic properties, Limitations of CFT, Ligand field Theory - nephelauxetic effect - MO theory – sigma – and pi-bonding in complexes and evidences for π-bonding – angular overlap model.

Unit-IV Studies of Coordination Compounds in Solution

Detection of complex formation in solution – Stability constants – stepwise and overall formation constants – simple methods (Potentiometric, pH metric and photometric methods) of determining the formation constants - factors affecting stability – Irving-William series - statistical and chelate effects – forced configurations.

Unit-V Reaction mechanisms in coordination chemistry

Electron transfer reactions – Inner sphere (ISET) and outer sphere (OSET) electron transfer processes. Role of bridging ligand with ISET reaction – tunneling transfer – multiple bridging in the activated complex in the ISET process. Complimentary and non-complimentary ET reactions. Cross reactions and Marcus Hush theory. Reaction mechanism of coordination compounds – Reaction Mechanism: Kinetics and mechanism of reactions in solution – labile and inert complexes – Types of ligand substitution reactions – mechanism; Dissociative mechanism (D), Associative mechanism (A) interchange mechanism (I), Substitution Reaction in octahedral complexes – general mechanism, general rate law for A,D and I - distinction between D, Id, IA pathways, replacement of coordinated water, mechanism of acid hydrolysis, base hydrolysis – DCB mechanism – direct and indirect evidences in favour of the mechanism. Ligand substitution reactions without cleavage of M-L Bond - Anation Reactions. Substitution in square planar complexes – General mechanism, Trans effect, influences of entering and leaving groups. Application of trans effect – synthesis of isomers of Pt(II) complexes – theories of trans effect and cis-trans isomerisation. reaction. Application of substitution reactions in the synthesis of Platinum and Cobalt complexes. isomerisation and racemisation reactions of complexes – reactions of four and six-coordinate complexes – interconversion between stereoisomers.

Reference Books:

1. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K.Medhi, Inorganic Chemistry - Principles of Structure and Reactivity, 4th edition, Pearson Education, 2006.
2. P. W. Atkins and, J. Paula, Physical Chemistry, Oxford Publications, 8thedition, 2009.
3. B. Douglas, D. McDaniel and J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd edition, John Wiley & Sons, 2010.
4. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, 3rd ed. Wiley-Eastern Company, New Delhi, 1990.
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9. D.M. Adams, Inorganic Solids: An Introduction to Concepts in Solid State Structural Chemistry, Wiley, 1974.
10. C.N.R. Rao and K.J. Rao, Phase Transitions in Solids, McGraw Hill, 2010.
11. M. C. Day, J. Selbin, Theoretical Inorganic Chemistry, East West Press. 2nd Ed, 1985.
12. S. F. A. Kettle, Physical Inorganic Chemistry – A Coordination Chemistry Approach, Spectrum Academic Publishers, Oxford University Press, 1996.
13. F. Basolo, R. G. Pearson, Mechanism of Inorganic Reactions, John Wiley, New York,1967.
14. G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3rd edition, Pearson, 2004.
15. C. E. Housecraft and A.G. Sharpe, Inorganic Chemistry, 4th edition, Pearson, 2012.
16. K. F. Purcelland, J. C. Kotz, Inorganic Chemistry, Cengage Learning, 2012.
17. M. C. Day Jr., J. Selbin, Theoretical Inorganic Chemistry, Literary Licensing, LC, 2012.
18. G. Wilkinson, R. D. Gillarsand J. A. McCleverty, Comprehensive Co-ordination Chemistry, Pergamon Press, 1987.
19. G. Wulfberg, Inorganic Chemistry, University Science Books, 2000.
20. D.M. Adam, Inorganic Solids: An introduction to concepts in solid-state structural chemistry, John Wiley & Sons, 1974.

21. G.E. Rodger, Inorganic and Solid State Chemistry, Cengage Learning India, Edition, 2002.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	2	2	2	3
2	2	1	3	3	3
3	2	2	3	3	3
4	2	1	2	3	3
5	3	2	1	2	3

Semester: VII **Course Type: Theory** **Course Code: CHE1072**
Credit: 4 **Course Title: Organic Chemistry-IV**

Course Outcomes		Level
CO-1	Relate thermodynamic stability and reaction rates	**Understand**
CO-2	Predict the aromaticity of organic compounds based on applying various rules	**Apply**
CO-3	Demonstrate the detailed mechanism of nucleophilic and electrophilic substitution reactions	**Understand**
CO-4	Sketch the importance of stereochemistry to predict the reactivity based on various stereochemical factors	**Apply**
CO-5	Learn the preparation and properties of various heterocyclic compounds including fused ring compounds	**Remember**

Unit-I Physical Organic Chemistry

Thermodynamic stability – general relationship between thermodynamic stability and reaction rates – electronic substituent effects on reaction intermediates – Principles of microscopic reversibility –substituent effects – solvent effects – methods of determination of reaction mechanism - kinetic methods – primary and secondary kinetic isotopic effect – non kinetic methods – isotope labeling, crossover experiment, trapping of intermediates, stereochemical studies. Linear free energy relationships: Hammett plot, steric and polar effects – Taft parameters. Solvent effects-Grunwald-Weinstein plots.

Unit-II Aromaticity

Criteria for aromaticity – Huckel's theory of aromaticity- energy, structural and electronic criteria for aromaticity – relationship among them. Craig's rule – non-benzenoid aromatic compounds. Aromatic, antiaromatic and homoaromatic compounds. Five-, six-, seven- and eight-membered rings and other systems. Aromaticity in annulenes, polycyclic compounds, charged rings - aromatic cations and anions, fused rings. Heteroaromatic systems. Aromaticity in sydnones and fullerenes

Unit-III Nucleophilic Substitution

Aliphatic nucleophilic substitution: S_N1, S_N2, borderline, S_Ni mechanisms and their stereochemistry. Factors affecting the rates of S_N1, $S_N2$and S_Ni and neighbouring group participation. Mechanisms of Rearrangement of Carbocations, Bridged (Non-classical) Carbocations. Substitution vs elimination reaction.

Aromatic electrophilic and nucleophilic substitutions: Mechanism, factors influencing ipso substitution and directive effect.

Unit-IV Stereochemistry

Configuration, conformation of cycloalkanes: four, five and six-membered rings, Conformational analysis of substituted cyclohexanes. conformation and reactivity. Conformation of fused and bridged ring systems-decalin, norbornane. anomeric effect. Stereochemistry of molecules with N, S, P chiral centers, allenes, spiranes, biphenyls, molecules with chiral planes, helical chirality. Topicity, prostereoisomerism, stereoselective and stereospecific reactions, enantioselective reactions, determination of enantiomeric and diastereomeric excess, double stereo-differentiation, asymmetric synthesis – substrate chirality, chiral auxiliaries, chiral reagents and

chiral catalysts. Resolution – optical and kinetic, chemo-, regio - and stereo-selective transformations, Sharpless asymmetric epoxidation.

Unit-V Heterocyclic Compounds-II

Nomenclature, five and six membered heterocycles, Heterocyclic compounds with one heteroatom: Preparation, properties and reactions of pyrrole, furan, thiophene and pyridine. Heterocyclic compounds with two heteroatoms: Preparation, properties and reactions of imidazole, pyrazole, oxazole, isoxazole, thiazole, isothiozole, pyrimidine, pyrazine, pyridazine. Heterocyclic compounds with three hetero atoms: Preparation, properties and reactions of triazole, triazine. Fused or condensed heterocyclic compounds: Preparation, properties and reactions of indole, quinoline, isoquinoline, carbozole.

Reference Books:

1. E. V. Anslyn, D. A. Dougherty, Modern Physical Organic Chemistry, University Science Books, 2004
2. Raj K. Bansal, Heterocyclic Chemistry, 4th Ed., Anshan Limited, 2008.
3. Alan R. Katritzky, Christopher A. Ramsden, John A. Joule, Viktor V. Zhdankin Handbook of Heterocyclic Chemistry, Elsevier Publication, 2010.
4. I. L. Finar, Organic Chemistry, Vol II, 6th Ed, Pearson Education, 2002.
5. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
6. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford University Press, 2014.
7. Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8nd Ed., Wiley Publications, 2019
8. Graham Solomons, T. W. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
9. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
10. I. L. Finar, Organic Chemistry, Vol I, 6th Ed, Pearson Education, 2002.
11. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Ed., Orient Longman, New Delhi, 1988.
12. Francis A. Carey and Richard J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, 5th Ed. 2007
13. Daniel E. Levy, Arrow Pushing in Organic Chemistry-An easy approach to understanding reaction mechanisms, Wiley Publications, 2008
14. Robert B. Grossman, The Art of Writing Reasonable Organic Reaction Mechanisms, 2nd Ed, Springer, 2003
15. L. G. Wade, Organic Chemistry, 6th Ed. Pearson, 2006
16. Francis A. Carey, Robert M. Giuliano, Organic Chemistry, 8th Ed. 2008
17. Peter Vollhardt, Neil Schore, Organic Chemistry-Structure and Function, 6th Ed. W. H. Freeman and Company, 2011
18. Thomas H. Lowry, Kathleen Schueller Richardson, Mechanism and Theory in Organic Chemistry, Harper and Row Publishers
19. Edwin S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Publications, 1959

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	3	3	2
2	2	1	3	3	2
3	2	1	3	3	1
4	2	1	3	3	1
5	2	1	2	3	1

Semester: VII **Course Type: Theory** **Course Code: CHE1073**
Credit: 4 **Course Title: Physical Chemistry-IV**

Course Outcomes		Level
CO-1	Know the basic concepts involved in chemical kinetics *i.e.* reaction rate, order and different types of reactions	**Knowledge**
CO-2	Understand the rate theory and to derive equations involved in heterogeneous catalysis and enzyme catalysis	**Understand**
CO-3	Analysis the kinetics of fast chemical reactions by different methods	**Analyze**
CO-4	Identify the point group of molecules and apply the concept of group theory to predict the spectroscopic properties	**Apply**

Unit-I Chemical Kinetics and Rate theories

Introduction- Reaction rates and order and molecularity of reaction, Determination of order – differential method and integration method. Theories of reaction Rates-Collision theory, Statistical mechanics, inclusion of steric factor and Conventional Transition State theory (CTST). Determination of rate constants with various methods in CTST, Comparison of collision theory with CTST, Arrhenius equation- characteristics, Significance of energy of activation, Temperature coefficient and its evaluation. Thermodynamic formulation of CTST and limitations.

Unit-II Chemical Dynamics

Potential energy surfaces, Dynamics of Unimolecular reactions – Lindemann-Hinshelwood – Rice Ramsperger Kassel (RRK) theory and Rice Ramsperger Kassel - Marcus (RRKM) theory. Kinetics of chain reactions (H_2-Cl_2 and H_2-Br_2 reactions) using steady-state treatment.

Experimental methods for the study of fast reactions-flow and Shock methods-chemical relaxation methods, T-jump and P-jump methods, Molecular beam methods, Flash photolysis, Introduction to femto-chemistry.

Unit-III Chemical Kinetics and Catalysis

Heterogeneous catalysis: Unimolecular and bimolecular surface reactions, Inhibition effect, determination of activation energy, Bi-molecular surface Reaction-Langmuir-Hinshelwood and Langmuir-Rideal mechanism.

Enzyme catalysis - Michelis-Menten equation, Effect of pH and temperature on enzyme catalysis.

Unit-IV Group Theory - Point Group and GOT

Point Group: Fundamentals Concept of Symmetry, Matrix representation of symmetry operations. Concepts of groups, molecular point groups, representation of groups, matrix representation of symmetry operations, reducible and irreducible representations, symmetry criterion of optical activity, symmetry restrictions on dipole moment.

Great Orthogonality Theorem: Interpretation of character tables, determination of symmetry species for translations and rotations. Transition moment integral, vanishing of integrals, symmetry aspects of molecular vibrations, vibrations of polyatomic molecules.

Unit-V Applications of Group theory in Chemistry

Applications in spectroscopy

IR spectra: Selection rules for vibrational absorption - Symmetry of normal modes of H_2O, C_2H_4, trans-N_2F_2, $CHCl_3$and NH_3 using Cartesian coordinates and internal coordinates, IR activity.

Raman Spectra: Complementary of IR and Raman spectra-determination of the Raman active vibrational modes.

Electronic spectra: Selection rules for electronic transition, electronic transitions of simple molecules.

Applications in chemical bonding

Transformation of atomic orbitals: Symmetry adapted linear combinations (SALC), Construction of hybrid orbitals for AB_3(planar), AB_4(Td), AB_5(D_3h) and AB_6(Oh) type of molecules

Ligand field theory: splitting of d orbitals in different environments using group theoretical considerations

MO diagram for water and ammonia, method of descending symmetry

Reference Books:

1. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York, 1988.
2. F. Daniels and R. A. Alberty, Physical Chemistry, 8h Edition, Wiley, New York, 1994.
3. P. W. Atkins, Physical Chemistry 8th Edn., Wiley, New York, 2006.
4. J. Rajaram, J.C. Kuriakose, Kinetics and Mechanisms of Chemical Transformations, Macmillan India, 2000.
5. K. J. Laidler, Chemical kinetics, 3rd Edn. Harper & Row, 1987.
6. C. Kalidas, Chemical Kinetic Methods: Principles of Fast Reaction Techniques and Applications, New Age International, 2005.
7. D.A. McQuarrie, J. D. Simon, Physical chemistry: A Molecular Approach, University Science Books,1997.
8. F. A. Cotton: Chemical Applications of Group Theory, Wiley Eastern, 1985.
9. P. K Ghosh and P. K Shukla: Atomic Electronic Structure, Prentice Hall of India,1994.
10. V. Ramakrishnan and M. S. Gopinathan: Group Theory in chemistry, Vishal Publication, 1986.
11. D. M. Bishop, Group theory and Chemistry, Dover, 1989.
12. B. S. Garg, Chemical Applications of Molecular Symmetry and Group Theory, Macmillan Publishers India Ltd, 2012

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	1	2	1
2	2	1	3	2	1
3	3	1	3	2	1
4	3	1	3	2	1

Semester: VII **Course Type: Practical** **Course Code: CHE1074**
Credit: 4 **Course Title: Organic Chemistry Laboratory-IV**

Course Outcomes		Level
CO-1	Acquire the knowledge of multistep organic synthesis in microwave assisted synthesis and photochemical reactions	**Understand**
CO-2	Organize experiments based on the organic preparations and qualitative analysis	**Analyze**
CO-3	Use knowledge of the purification techniques	**Apply**
CO-4	Report separation of two mixture present in the organic compounds	**Understand**
CO-5	Support on estimation of organic compounds *viz* volumetric methods	**Evaluate**

Students are expected to try various approaches in organic synthesis and characterization. The assessment is based on the practical skills in the lab, originality and the written report at the end of the course. Topics include but are not restricted to the below points.

Multistep organic synthesis (any four) - conventional synthesis - microwave assisted synthesis - photochemical reactions. Purification of the compounds using column chromatography and characterization of the compounds using spectroscopic techniques.

Qualitative Analysis: Separation and analysis of organic mixture containing two components.

Estimation of Organic Compounds

(a) Estimation of phenol and aniline - volumetric method.
(b) Estimation of glucose by Betrands method.
(c) Estimation of methyl ketone – iodimetric method
(d) Determination of iodine and saponification value of an oil sample.

Reference Books

1. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Textbook of Practical Organic Chemistry, Prentice-Hall, 5th Ed, 1996.
2. F. G. Mann, B. C. Saunders, Practical Organic Chemistry, 4th Ed, Pearson Education India, 2009.
3. B. Haynes, Qualitative Organic Analysis, Pearson Education, 2011.
4. P. B. Cranwell, L. M. Harwood, C. J. Moody, Experimental Organic Chemistry, 3rd Ed, Wiley-Blackwell, 2017.
5. V. K. Ahluwalia, R. Aggarwal, Comprehensive Practical Organic Chemistry, Universities Press, 2004.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	3	3	3
2	2	3	3	3	3
3	2	3	3	3	3
4	2	3	3	3	3
5	2	3	3	3	3

Semester: VIII **Course Type: Theory** **Course Code: CHE1081**
Credit: 4 **Course Title: Inorganic Chemistry-V**

Course Outcomes		Level
CO-1	Gain knowledge on structure and bonding in organometallic compounds	**Knowledge**
CO-2	Apply organometallic chemistry principles in catalysis	**Apply**
CO-3	Gain knowledge in Bioinorganic chemistry and role of metals in biology	**Remember**
CO-4	Grasp the basics of metalloenzymes and related assessment	**Remember**
CO-5	Understand magnetic properties of inorganic compounds and photochemistry	**Understand**

Unit-I Structure and bonding in organometallics

16/18-Electron rule – Preparation, Structure, Bonding – spectra of metal alkyls, aryls, hydrides, dihydrogen and dinitrogen complexes - metallocenes - electronic structure and bonding in ferrocene - synthesis, physical and spectroscopic properties of metallocenes – fluxional molecules. σ–bonded ligands: metal- phosphines, Nitrosyls – bridging and terminal nitrosyls, bent and linear: structures, reactivity and bonding. Carbenes: N-heterocyclic carbenes, Fischer carbenes, Schrock carbenes, carbynes. Isolobal analogy, metal-metal bonds, transition metal clusters. Quintuple bond. Template synthesis of macrocyclic ligands.

Unit-II Reaction mechanisms and catalysis

Important types of reactions of organometallic compounds – substitution – electrophilic and nucleophilic attack on ligands; carbonylation and decarbonylation; oxidative addition, reductive elimination, insertion, hydride elimination, abstraction; Catalysis: Hydrogenation of olefins, hydroformylation, Wacker process, Ziegler-Natta polymerisation, cyclooligomerisation, Isomerization reactions, olefin metathesis, Monsanto acetic acid synthesis, Fischer-Tropsch process, hydrosilylation, carbonylation, and CH functionalization reactions.

Unit-III Transport and storage of Metal ions in Biology

A brief introduction to bioinorganic chemistry - Transport and storage of metals: Mechanism – Fe, Cu, Zn and V storage and transport – metallothioeins. Basics of Biomineralization. Sodium and potassium ion pumps - mechanisms of ion-transport across cell membranes – bleomycin - siderophores (e.g. enterobactin and desferrioxamine) -transport of iron by transferring - storage of iron by ferritin - biochemistry of calcium as hormonal messenger - Role of Ca^{2+} in blood clotting. Metals at the Center of Photosynthesis: Primary Processes in Photosynthesis – Photosystems I and II - Light Absorption (Energy Acquisition) – Exciton transport (Direct Energy Transfer) – Charge separation and electron transport – Manganese catalyzed oxidation of water to O_2.

Unit-IV Metalloporphyrins and Metalloenzymes

Dioxygen transport and storage - hemoglobin and myoglobin: electronic and spatial structures - hemerythrin and hemocyanine – synthetic Oxygen carriers, model systems - blue copper proteins (Cu) - iron-sulfur proteins (Fe) - cytrochromes electron transport chain - carbon monoxide poisoning - iron enzymes - peroxidase, catalase and cytochrome P-450, copper enzymes - superoxide dismutase, carboxypeptidase, carbonicanhydrase, vitamin B_{12} and B_{12} coenzymes, nitrogen fixation. Essentials of trace elements and chemical toxicology: Trace elements in

biological system. Metal ion toxicity - classes of toxic metal compounds – detoxification. Metals in medicine: Anti arthritis drugs – Au and Cu in rheumatoid arthritis – Li in psychiatry – Pt, Au and metallocenes in anti-cancer drugs- metals in radio-diagnosis and magnetic resonance imaging.

Unit-V Nuclear Chemistry II

Natural radioactivity – Detection and measurement of radioactivity: Geiger Muller and ionization counters. Radioactive series including neptunium series – group displacement law – Rate of disintegration and half-life period – Average life period. Artificial radioactivity – induced radioactivity – uses of radioisotopes – hazards of radiations – nuclear energy – nuclear reactors – nuclear fission and fusion – product yields – Spallation – photonuclear and thermo nuclear reactions – energy source of the sun and stars – carbon dating – rock dating. radioactive waste disposal – applications of nuclear science in agriculture – Atomic power projects in India. Nuclear medicine- Single Proton Emission Tomography (SPECT) and Positron Emission Tomography (PET).

Reference Books:

1. P. Powell, Principles of Organometallic Chemistry, 2nd ed., Springer, 1998.
2. K. F. Purcell and J. C. Kotz, Inorganic Chemistry, Saunders Golden Sunburst Series, W.B. Saunders Company, Philadelphia, 1987.
3. J. E. Huheey, E. A. Keiter, R. L. Keiterand, O. K. Medhi, Inorganic Chemistry - Principles of Structure and Reactivity,4th edition, Pearson Education, 2006.
4. R. C. Mehrotra, and A. Singh, Organometallic Chemistry, a Unified Approach, New Age International, 2006.
5. R. H. Crabtree, Organometallic Chemistry of the Transition Metals, 5thEd.Wiley, New York, 2009.
6. B. D. Gupta, and A. J. Elias, Basic Organometallic Chemistry: Concepts, Syntheses, and Applications of Transition Metals, 1st edition, Universities Press, CRC Press, 2010.
7. S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry, Panima Publishing Company, New Delhi, 1997.
8. W. Kaimand, B. Schewederski, Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, John Wiley & Sons, New York, USA, 2013.
9. I. Bertini, H. B. Gray, S. J. Lippardand, J. S. Valentine, Bioinorganic Chemistry, 1st South Asia edition, Viva books Pvt. Ltd., 2007.
10. S. P. Banerjee, Advanced Inorganic Chemistry, Arunabha Sen, Books and Allied (P) LTD. Volume II, 2015.
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CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	2
2	1	2	1	2	1
3	3	3	3	3	3
4	2	4	2	4	2
5	2	5	2	5	2

Semester: VIII **Course Type: Theory** **Course Code: CHE1082**
Credit: 4 **Course Title: Organic Chemistry-V**

Course Outcomes		Level
CO-1	Synthesize organic compounds based on light mediated route	**Understand**
CO-2	Compare the concepts of pericyclic reaction mechanism for thermal and photochemical reactions	**Remember**
CO-3	Demonstrate the detailed mechanism of various name reactions deals with C-C, C-N and C-O bond formation	**Apply**
CO-4	Make a reaction chart on oxidizing reagents and how to apply in the chemical world and research aspects	**Apply**
CO-4	To demonstrate the use of reducing reagents in the synthetic organic chemistry	**Understand**

Unit-I Organic photochemistry

Thermal vs photochemical reactions. Photochemistry of alkenes, dienes and polyenes. Norrish type I and type II, and Patterno–Buchi reactions. Intramolecular reactions of carbonyl compounds, saturated cyclic and acyclic compounds, α,β and β,γ- unsaturated compounds, cyclohexanone and cyclohexadienones Photochemical rearrangement: di-pi-methane, oxa/aza di-pi methane, Photo-Fries, Lumiketone and Barton rearrangement. Intermolecular cycloaddition reactions and dimerisation. Photochemistry of aromatic compounds - isomerizations, additions, substitutions oxidation and reduction.

Unit-II Pericyclic Reactions

Molecular orbitals and symmetry: Frontier orbitals of ethylene, 1,3-butadiene, 1,3,5-hexatriene and allyl systems. Classification of pericyclic reactions, Electrocyclic reactions: Conrotation and disrotation in 4n, 4n+2, allyl systems and secondary effects. Analysis of Electrocyclic reactions: FMO and Woodward-Hoffmann correlation diagrams methods. Cycloaddition reactions: Effect of stereochemistry and substituents on the rate of cycloadditions, analysis of cycloaddition reactions. 1,3-Dipolar cycloadditions and cheleotropic reactions. Sigmatropic rearrangements - [1,2]-sigmatropic shifts involving carbon moieties. [m,n] and [m,m] sigmatropic hydrogen shifts. Claisen, Cope and Sommelet Hauser reactions.

Unit-III C-C, C-N, and C-O/S bond formation

C-C bond formation: Aldol, Arndt-Eistert, Bardhan-Sengupta, Barbier, Baylis-Hillman, Benzoin, Michael, Perkin, Robinson annulations, Vilsmeier, and Ullmann Reactions. C-N bond formation: Mannich, Mitsunobu, Ritter, Ugi, Doebner, Buchwald-Hartwig, and Stork enamine reactions. Formation of azides and hydrazines. C-O and C-S bond formation –Fischer esterification, Williamson's ether synthesis, Prins, Darzen, and Mitsunobu reactions.

Unit-IV Oxidation

Alcohols to carbonyl compounds-chromium(VI) oxidants, dimethyl sulfoxide - Swern oxidation, manganese(IV) oxide, silver carbonate, hypervalent iodine(III) and (V) reagents, ceric ammonium nitrate (CAN), N-oxyl radical. Alkenes to epoxides by H_2O_2, hydroperoxides and peroxyacids. Prevost oxidation and Woodward modifications. Oxidative cleavage of 1,2-diols - periodic acid. Oxidation of allylic and benzylic C-H bonds - NBS, DDQ, chloranil-T, SeO_2, and TEMPO. PCC, Oppenauer and Corey-Kim oxidation.

Unit-V Reduction

Catalytic hydrogenation - homogeneous and heterogeneous catalytic reductions. Dissolving metal reductions. Non-metallic reductions - Wolff-Kishner, diimide reductions, and Hantzsch ester. Metal hydride reductions - Nucleophilic metal hydrides, Sodium cyano borohydride, Li and Na borohydrides, $LiAlH_4$, DIBAL-H and Red-Al. Electrophilic metal hydrides - BH_3 and AlH_3. Hydrogenolysis - use of tri-n-butyl tin hydride. Reduction using SmI_2. Noyori and Knowels asymmetric hydrogenation.

Reference Books:

1. V. Ramamurthy, Organic Photochemistry, CRC Press, 1997.
2. J. M. Coxon, B. Halton, Organic Photochemistry, Cambridge University Press, 1987
3. G. R. Chatwal, Organic Photochemistry, Himalaya Publishing House, 1998.
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5. Ian Fleming, Pericyclic Reactions, Oxford University Press, 2015.
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CO	Program Outcomes				
	1	2	3	4	5
1	3	1	3	3	2
2	3	1	3	3	2
3	3	1	3	3	1
4	3	1	3	3	1
5	3	1	3	3	1

Semester: VIII **Course Type: Theory** **Course Code: CHE1083**
Credit: 4 **Course Title: Physical Chemistry-V**

Course Outcomes		Level
CO-1	Apply the advanced quantum chemical methods for solving many-electron systems	**Apply**
CO-2	Solve Schrodinger equation for the simple molecules using perturbation, variation and HF methods	**Create**
CO-3	Demonstrate the applications of LCAO theory and direct bonding in polyatomic molecules	**Apply**
CO-4	Understand pulse sequences in magnetic resonance spectroscopy and apply advanced spectroscopy techniques in the experiments	**Understand**

Unit-I Quantum Chemistry-II

Potential energy of hydrogen-like systems: Wave functions and energy of hydrogen like atoms. angular-radial functions - and their plots. The postulate of spin by Uhlenbeck and Goudsmith-Spin orbitals- Construction of spin orbitals from spin functions. Quantization of angular momentum, quantum mechanical operators corresponding to angular momenta (Lx, Ly, Lz and L^2), commutation relations between these operators. Spherical harmonics as Eigen functions of angular momentum operators Lz and L^2. Ladder operator method for angular momentum. Space quantization. Schrödinger equation for many electron atoms: Helium and Lithium atoms.

Unit-II Approximation Methods

Born-Oppenheimer approximation, Perturbation theory, Variational methods, Hartree-Fock equations, Self-consistent field method for solving Hartree-Fock equations, Anti-symmetric wave function, Slater determinant wave function, Molecular Hamiltonian operators.

Valence bond treatment for chemical bonding in molecules - molecular orbitals, Molecular orbital theory for different diatomic molecular systems, photoelectron spectra, SCF-LCAO-MO wave function. Electronic states of diatomic molecules -sp, sp^2 and sp^3 hybrid orbitals. Molecular term symbols, Hückel molecular orbitals, bonding in polyatomic molecules.

Unit-III EMR and Origin of spectra

Nature of EMR, Interaction of EMR with matter, Natural line width and intensity of spectral lines, Classical and quantum chemical approach to absorption of radiation by molecules. Energy levels in molecules. Born Oppenheimer approximation, Population of energy levels. LASER – three & four level

Unit-IV Optical Spectroscopy-III

Microwave spectroscopy: Molecular classification and Rotation spectra, Diatomic and polyatomic molecules. Application of Rotation spectra (Bond length, Isotopic mass, dipole moment, isotopic abundance), Non-rigidity of rotor.

Vibrational spectroscopy: Vibrational spectra of diatomics & SHO; anharmonicity & Morse potential; Vibration-rotational spectra of diatomics, polyatomic Molecules-P, Q&R branches, Dispersive IR & FTIR, Vibration spectra of polyatomic molecules. Normal modes of vibrations of polyatomic molecules, Coupling of rotation and vibration, Parallel and perpendicular bands, Breakdown of Born-Oppenheimer Approximation,

Unit-V Optical Spectroscopy-IV

Raman Spectroscopy: Polarizability and classical theory of Raman spectrum, Rotational Raman spectra. Vibrational Raman spectra, mutual exclusion principle, Surface enhanced Raman spectra, Resonance Raman,

Electronic Spectroscopy: Electronic energy states of molecules. Vibrational structure of electronic bands, Electronic transitions and absorption bands, Selection rules, Electron spectroscopy for chemical analysis (ESCA)-UPS, X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), Inductively coupled plasma mass spectrometry (ICP-MS)

Reference Books:

1. I. N. Levine: Quantum Chemistry, Prentice Hall India, 1994.
2. S. N. Datta: Lecture on Chemical bonding and quantum chemistry, 1998.
3. D. A. McQuairrie: Quantum Chemistry, Oxford University press, Oxford, 1982.
4. P. W Atkins: Molecular Quantum Mechanics, Clarendon Press, Oxford, 1983.
5. R. K. Prasad: Quantum Chemistry through Problems and Solutions, New Age International, 1997.
6. F. L. Pilar: Elementary quantum chemistry, Mc-Graw Hill International, 2ndEdn.1990.
7. A. K Chandra: Introduction to Quantum Chemistry, Tata Mc-Graw Hill, 1988.
8. P. W. Atkins, Physical Chemistry, Oxford, London, 6th Edn, 1998.
9. R. Sindhu, Molecular Spectroscopy, Tata McGraw Hill, 1986.
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14. A. Dau and C. Singh, Quantum chemistry classical to computational, Manakin press, 2017.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	2	3	2	2
2	3	2	3	2	2
3	3	2	3	2	2
4	2	2	3	2	2

Semester: VIII **Course Type: Theory** **Course Code: CHE1084**
Credit: 4 **Course Title: Physical Methods in Chemistry-I**

Course Outcomes		Level
CO-1	Demonstrate the utility of UV-visible, IR and fluorescence spectroscopy in structural characterization	**Apply**
CO-2	Elucidate the structure of organic compounds based on ^{1}H and ^{13}C NMR spectroscopy	**Evaluate**
CO-3	Explicate the applications of two-dimensional NMR spectroscopic techniques for structural elucidation	**Understand**
CO-4	Identify the fragmentation patterns of compounds and solve the structure of compounds using mass spectrometry	**Evaluate**
CO-5	Structural elucidation of unknown compounds using UV-vis, IR, Mass and NMR techniques	**Apply**

Unit-I UV-Visible, Fluorescence Spectroscopy and ORD-CD

Basics of UV Spectroscopy, factors governing absorption maximum and intensity. Woodward Fieser and Fieser-Kuhn's rules - calculation of λmax for simple organic molecules. Fluorescence - principles Stokes shift, quantum yield and application.

ORD-CD: Circular bireferegence, optical rotary dispersion, circular dichroism – Cotton effect curves – octant rule –axial haloketone rule - Applications of chiroptical properties in configurational assignments.

Unit-II Infra-Red Spectroscopy

Principle, instrumentation and sampling technique- Hook's law, vibrational frequency, modes of vibrations, and selection rules. Factors influencing vibrational frequency. Fingerprint and functional group region. Interpretation of the IR spectra of alkane, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenol, carbonyl compounds, amines and heterocyclics– related problems

Unit-III NMR Spectroscopy-I

^{1}H NMR, Spectral parameters – intensity, chemical shift, multiplicity, coupling constant, factors affecting chemical shift. Analysis of first order and second – order spectra – shift reagents - structure determination of organic compounds by ^{1}H NMR spectra. Chemical shifts and coupling constants (spin-spin coupling) involving different nuclei (^{1}H, ^{19}F, ^{31}P, ^{13}C) interpretation. Examples for different spin systems – Effect of quadrupolar nuclei (^{2}H, ^{10}B, ^{11}B) on the ^{1}H NMR spectra, – study of fluxional behavior of molecules.

Unit-IV NMR Spectroscopy-II

^{13}C NMR: Proton coupled; off–resonance decoupled; proton noise decoupled ^{13}C NMR spectra, DEPT techniques. Assignment of chemical shifts, additively effect, characteristic chemical shifts of common organic compounds and functional groups.

NMR of paramagnetic molecules – isotropic shifts contact and pseudo-contact interactions – Lanthanide shift reagents. An elementary treatment of second order spectra – examples.

2D NMR techniques: H,H-COSY, C,H-COSY, HMBC, NOESY and INADEQUATE.

Unit-V Mass spectrometry

Instrumentation – methods of ionisation - EI, CI, APCI, ESI, MALDI and FAB. Mass analyser – magnetic and electrostatic sector, time of flight and quadrupole. Molecular ion, base peak, multicharged ion, metastable ions and isotope ratio. Fragmentation patterns of saturated, unsaturated and aromatic hydrocarbons, alcohols, phenols, aldehydes, ketones, carboxylic acids, esters, amines, nitro, nitrile and halides. McLafferty rearrangement.

Structural elucidation using UV-Visible, IR, Mass, ^{1}H, ^{13}C NMR and 2D-COSY techniques

Reference Books:

1. R. M. Silverstein and F. X. Webster, Spectrometric identification of organic compounds, John Wiley and Sons. Inc., 6th edition, 1997.
2. W. Kemp, Organic Spectroscopy, 3rd edition, MacMillan, 1994.
3. Jag Mohan, Organic Spectroscopy: Principles & Applications, Narosa Publishers, 2012.
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6. Paul S. Pregosin, NMR in Organometallic Chemistry, Wiley, 2013.
7. R. S. Drago, Physical Methods for Chemistry, 2nd Edition, Saunders College Publishing, 1992.
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9. D. H. Williams and Ian Fleming, Spectroscopic methods in organic chemistry, Tata McGraw Hill, 1998.
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11. L. D. S. Yadav, Organic Spectroscopy, Kulwer academic publishers, 2004.
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14. A Derome, Modern NMR Technique, Pergamon, 1983.
15. Farrar and E. D. Becker, Pulsed FT NMR Spectroscopy.
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17. C. P. Slichter, Principles of Magnetic Resonance, Third Edition, Springer-Verlag, 1990.
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CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	3	1	2	2	2
2	3	1	2	2	2
3	3	1	2	2	2
4	3	1	2	2	2
5	3	1	2	2	2

Semester: VIII **Course Type: Practical** **Course Code: CHE1085**
Credit: 4 **Course Title: Physical Chemistry Laboratory-IV**

Course Outcomes		Level
CO-1	Understand the instrumentation methods involved in the experiments	**Understand**
CO-2	Perform or develop working models	**Create**
CO-3	Gain the required experimental skills for career development	**Create**
CO-4	Apply QM methods for modelling simple organic/inorganic compounds for structural optimization and reaction modelling	**Apply**

Part A: List of Wet Lab Chemistry (Any 10-12 Experiments)

1. *Surface Chemistry*
   (a) Verification of adsorption isotherms (Freundlich and Langmuir): charcoal-acetic acid or charcoal-oxalic acid system.
   (b) Kinetics & Determination of surface area by adsorption of acetic acid on Charcoal.
2. *Phase Diagram*
   (a) Determination of the concentration of the electrolyte using CST of phenol-water system.
   (b) Three Component Liquid Systems: Acetic Acid – Chloroform – Water
3. *Partition Coefficient*
   (a) Partition coefficient of benzoic acid between benzene and water.
   (b) Molecular formula of copper-ammonia complex by the partition coefficient method.
4. *Spectroscopy*
   (a) Formation kinetics of Chromium-EDTA complex (Spectrometry).
   (b) Simultaneous Estimation of Manganese and Chromium in a Solution of Dichromate and Permanganate Mixture.
   (c) Photocalorimetric determination of Bimolecular rate constant.
5. *Surface Tension*
   (a) Determine the surface excess of amyl alcohol.
6. *Potentiometry*
   (a) Titration of a strong and weak Acid Mixture with a Strong Base-Potentiometry.
   (b) Determination of stability constant of silver diammine complex by potentiometric titrations.
   (c) Dissociation of a weak acid by potentiometric titration.
7. *Conductometry*
   (a) Verification of Ostwald's dilution law and determination of dissociation constant of weak acid.
   (b) Conductometric titrations of a mixture of acids Vs strong base.
   (c) Van't Hoff's factor of benzoic acid between benzene and water.
   (d) Critical Micelle concentration of surfactant by conductivity measurements.
   (e) Verification of Onsager's Equation and Determination of Equivalent Conductance at Infinite Dilution of Strong Electrolytes.
   (f) Conductometric determination of Nickel using DMG.
8. *Kinetics*
   (a) Second order rate constant for the alkaline hydrolysis of ethyl acetate by conductivity measurements.

(b) Arrhenius parameters for the Acid–Catalysed Hydrolysis of Methyl acetate.

9. *Viscometry*

(a) Determination of molecular weight of a polymer by viscosity measurements.

10. *Additional*

(a) Specific and molar refraction of a liquid by Refractometry.

(b) Reversibility of a redox process and determination of concentration of a given solution by cyclic voltammetry.

(c) Inversion of Sucrose-Polarimeter.

Part B: List of Computational Chemistry Experiments (Any 3-4 Experiments)

1. Calculation of electrostatic charges of atoms in organic molecules using population analysis.
2. Calculation of Resonance energy of aromatic compounds.
3. Calculation of dimerization energy of carboxylic acids.
4. Perform the conformational analysis of butane using potential energy scan.
5. Find the transition state of simple organic reactions and plot the reaction profile.
6. Determination of heat of hydration of organic molecules.
7. Find the Gibbs free energy of simple gaseous phase reactions and calculate equilibrium constant.
8. Calculation of pKa of simple organic molecules and compare it with experimental values.
9. Docking studies involving protein ligand interactions.
10. Calculation of electrophilicity index in hard-soft acids and bases.

Reference Books:

1. J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2001.
2. G.W. Garland, J. W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8thEdn. McGraw Hill, 2009.
3. B. Viswanathan, Practical Physical chemistry, Viva Pub., 2005.
4. S. Kumar and N. Kumar, Physical Chemistry Practical, New Central Book Agency,2012.
5. A.M. James, F.E. Prichard, Practical Physical Chemistry Paperback, 1974.
6. J. Foresman& A. Frisch, Exploring Chemistry with Electronic Structure Methods, Gaussian Inc., 2000.
7. D.C. Young, Computational Chemistry: A Practical Guide for Applying Techniques to Real World Problems, John Wiley & Sons, 2001.
8. D. Rogers Computational Chemistry Using the PC, 3rdEdn, John Wiley & Sons,2003.
9. A.R. Leach, Molecular Modelling: Principles and Applications, 2ndEdn, Longman, 2001.
10. J. M. Haile, Molecular Dynamics Simulation: Elementary Methods, 2001.

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	2	2	3	3
2	3	3	3	3	3
3	3	3	3	3	3
4	3	3	3	3	3

Semester: IX **Course Type: Theory** **Course Code: CHE1091**
Credit: 4 **Course Title: Physical Methods in Chemistry-II**

Course Outcomes		Level
CO-1	Acquire knowledge on advanced concepts in spectroscopy thereby being able to interpret the spectra and solve the structure of metal complexes	**Remember**
CO-2	Discuss the application of electronic spectroscopy to simple coordination compounds and f-block elements	**Understand**
CO-3	Elucidate the structure of simple organometallic complexes by IR and Raman spectroscopic tools	**Apply**
CO-4	Determine the geometry of inorganic complexes using EPR spectroscopy	**Analyze**
CO-5	Depict the advanced spectroscopic tools like NMR, Mossbauer and NQR and its exploitation to express the structure of inorganic complexes	**Evaluate**

Unit-I Electronic Spectroscopy

Microstates, - terms and energy levels for d^1 - d^9 ions in cubic and square fields – Intensity of bands – group theoretical approach to selection rules - Effect of distortion and spin-orbit coupling on spectra- Orgel and Tanabe-Sugano diagrams – Evaluation of 10Dq and β for octahedral complexes of cobalt and nickel – applications to simple coordination compounds – charge transfer spectra – electronic spectra of $[Ru(bipy)_3]^{2+}$. Electronic Spectra of f-block elements.

Optical rotatory dispersion, circular dichroism and Magnetic circular dichroism – applications to metal complexes.

Unit-II Infrared and Raman Spectroscopy

IR spectroscopy- Introduction, selection rules, stretching frequency of some inorganic ions- effect of coordination on the stretching frequency- sulphato, carbonato, sulphito, aqua, nitro, thiocyanato, cyano, thiourea, DMSO complexes. Effect of isotopic substitution on the vibrational spectra of molecules – vibrational spectra of metal carbonyls with reference to the nature of bonding, geometry and number of C-O stretching vibrations, Raman spectroscopy – Introduction, combined applications of IR and Raman spectroscopy in the structural elucidation of N_2O, ClF_3, NO^{3-}, ClO_4, metal carbonyls.

Unit-III NMR and NQR Spectroscopies

Introduction to hetero-nuclear NMR, Factors influencing coupling constant (gyromagnetic ratio, periodicity, hybridisation, s-character, electronegativity, coordination number, trans influence, inter-bond angles, lone-pair and oxidation state) - structural assessment of simple inorganic compounds using ^{1}H, ^{13}C, ^{15}N, ^{19}F, ^{31}P-NMR spectroscopic techniques – Studies on fluxional molecules, quadrupolar nuclei-effect in NMR spectroscopy, shift reagents and applications. Overview of ^{13}C NMR of metal carbonyls, ^{119}Sn, ^{195}Pt, and other nuclei NMR and satellite spectra. NQR spectroscopy - Characteristics of quadrupolar nucleus – effects of field gradient and magnetic field upon quadrupolar energy levels – NQR transitions – applications of NQR spectroscopy.

Unit-IV EPR and Mössbauer spectroscopies

Theory of EPR spectroscopy - Spin densities and McConnell relationship – Factors affecting the magnitude of g and A tensors in metal species - Zero-field splitting and Kramers degeneracy – Spectra of VO(II), Mn(II), Fe(II), Co(II), Ni(II) and Cu(II) complexes – Applications of EPR to a few biological molecules containing Cu(II) and Fe(III) ions. Mössbauer spectroscopy - Isomer shifts – Magnetic interactions – Mossbauer emission spectroscopy – applications to iron and tin compounds.

Unit-V Magnetic and photochemical properties of Inorganic complexes

Types of magnetism – Dia –para – ferro and antiferro magnetism. Magnetic properties of free ions – first order Zeeman effect – Determination of Magnetic moments and their applications to the elucidation of structures of inorganic compounds – temperature dependent and temperature independent paramagnetism - Magnetic properties of lanthanides and actinides. Spin crossover in coordination compounds. Inorganic and organometallic photochemistry – principles- Unimolecular charge-transfer photochemistry of cobalt(III) complexes – mechanism of CTTM, photoreduction – ligand-field photochemistry of chromium(III) complexes – Adamson's rules, photoactive excited states, V-C model – photophysics and photochemistry of ruthenium – polypyridine complexes, emission and redox properties.

Reference Books:

1. R. S. Drago, Physical Methods for Chemistry, 2nd Ed, Saunders College Publishing, 1992.
2. A. B. P. Lever, Inorganic Electronic Spectroscopy, 2nd Sub Ed, Elsevier Science, 1986.
3. J. E. Huheey, E. A. Keiter and R. L. Keiter and O. K. Medhi, Inorganic Chemistry – Principles of Structure and Reactivity, 4th Edition, Pearson Education, 2006.
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6. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part B: Applications in Coordination, Organometallic, and Bioinorganic Chemistry, Wiley-Interscience; 5th edition, 1997.
7. J. Ferraudi, Elements of Inorganic Photochemistry, Wiley, New York, 1988.
8. E. A.V Ebsworth, D. W. H. Rankin and S. Cardock- Structural Methods in Inorganic Chemistry, 1987.
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21. R.B. Jordon, Reaction Mechanisms of Inorganic and Organometallic Systems, 3rd Edition, Oxford University Press, 2007.
22. C.J. Ballhausen and H.B. Gray, Molecular Orbital Theory, Benjamin/Cummings Pub. Co, 1965.
23. N. Figgis and M. A. Hitchman, Ligand Field Theory and Its Applications, 1st Edition, Wiley VCH, 1999.
24. S.F.A. Kettle, Physical Inorganic Chemistry – A Coordination Chemistry Approach, Spectrum Academic Publishers, Oxford University Press, 1996.

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	2	2	2	1
2	2	2	2	2	2
3	3	2	3	2	2
4	3	2	3	2	2
5	2	1	3	1	2

Semester: IX **Course Type: Theory** **Course Code: CHE1092**
Credit: 4 **Course Title: Organic Chemistry-VI**

Course Outcomes		Level
CO-1	Illustrate the application of organometallic reagents and coupling reactions in the field of synthetic organic chemistry	**Understand**
CO-2	Demonstrate synthetic route for various compounds through functional group interconversion	**Remember**
CO-3	Construct synthetic routes to achieve any given target molecules through retrosynthetic analysis	**Apply**
CO-4	Exemplify the significances of rearrangement transformations in organic synthesis	**Apply**
CO-5	Illustrate the stereochemistry, structural features and biological importance of steroids and prostaglandins	**Understand**

Unit-I Organometallic Reagents and Catalysts
Application of organometallic compounds of lithium, magnesium, boron, silicon and tin in organic synthesis. Applications of organoplatinum, organonickel, organocobalt, organocopper, organozinc, organocadmium and organomercury in organic synthesis.
Coupling Reactions: Mechanism and applications of Buchwald-Hartwig cross coupling, Kumada, Fukuyama, Heck Reaction, Hiyama, Sonogashira, Stille, Suzuki, Tsuji-Trost, Negishi, Enzymes and whole cell mediated biotransformations

Unit-II Synthetic Strategies-I: Functional Group Interconversions
Functional group interconversions, the importance of the order of events in organic synthesis, chemoselectivity, regioselectivity, and Umpolung concept. The concept of protection and deprotection of functional groups in synthesis. Protection of amino, hydroxy, diol, carbonyl and, double and triple bonds.

Unit-III Synthetic Strategies-II: Retrosynthesis
Disconnection Approach - synthons and synthetic equivalents, donor and acceptor synthons, disconnection, alternating polarity disconnection and steps in planning the synthesis. One and two groups C-X and C-C disconnections. disconnection of alcohols, olefins and ketones. Logical and illogical disconnections. Two group disconnection 1,2-, 1,3-, 1,4-, 1,5- and 1,6-dioxygenated skeletons and dicarbonyls. Control of relative stereochemistry and enatioselectivity in carbonyl condensations. Retro Diels – Alder reactions- Pericyclic reactions- Wieland Mischer ketone synthesis- Reterosynthesis of 3, 4, 5, 6 membered heterocycles containing two nitrogens. Designing synthesis: Disconnection approach in Epothilone, Juvabione and longifolene.

Unit-IV Rearrangement and Transformation Reactions
Classification of rearrangements. General mechanistic consideration, nature of migration, migratory aptitude, stereochemical aspects and memory effects in rearrangements. Rearrangement to electron deficient carbon - pinacol-pinacolone, Wagner-Meerwein, benzillic acid, Wolf, Rupe and Demjanov rearrangements. Rearrangement to electron deficient nitrogen - Hofman, Curtius, Schmidt, Lossen and Beckmann rearrangements. Rearrangement to electron deficient oxygen - Baeyer-Villiger rearrangement. Rearrangement to electron rich carbon -

Fovorskii, Wittig, Neber and Stevens rearrangements. Aromatic rearrangement - Fries, Claisen and benzidine rearrangements.

Unit-V Steroids and Prostaglandins

Steroids: Classification of steroids, biological importance- structure, and stereochemistry of cholesterol, Structural features of bile acids – Sex hormones – androsterone, testosterone, estrone, estradiol, progesterone - Structure of ergosterol.

Prostaglandins (PG): Types of PG's prostaglandins. Functions of prostaglandins. Synthesis of prostaglandins E_2, prostacyclin (PGI_2). Structural features (synthesis not required) of prostaglandin D_2 (PGD_2) and prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$).

Reference Books:

1. B. D. Gupta, Basic Organometallic Chemistry: Concepts, Syntheses and Applications, University Press, 2011
2. Robert H. Crabtree, The Organometallic Chemistry of the Transition Metals, Wiley, 2014
3. Norio Miyaura, S.L. Buchwald, Metal Catalyzed Cross-Coupling Reactions and More, 2003.
4. G. Denis Meakis, Functional Groups: Characteristics and Interconversions, Oxford Science Publications, 1996
5. Jie Jack Li, Name Reactions: A Collection of Detailed Mechanisms and Synthetic Applications, 5th Ed, Springer, 2014
6. Christian M. Rojas, Molecular Rearrangements in Organic Synthesis, John Wiley & Sons, Inc, 2015
7. S. Warren, P. Wyatt, Organic Synthesis: The Disconnection Approach, Wiley, 2008
8. P. Wyatt, S. Warren, Organic Synthesis: Strategy and Control, Wiley-Blackwell, 2007
9. R. O. C. Norman, J. M. Coxon, Principles of Organic Synthesis, 3rd edn, 1993
10. W. Carruthers, I. Coldham, Modern Methods of Organic Synthesis, 4th edn, Cambridge University Press, 2015
11. E. J. Corey, X. M. Cheng, The Logic of Chemical Synthesis, Wiley-India Private Ltd, 2011.
12. K. C. Nicolaou, E. J. Sorensen, Classics in Total Synthesis, Wiley-ECH, 1996
13. I. L. Finar, Organic Chemistry, Vol II, 6th Ed, Pearson Education, 2002.
14. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
15. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford University Press, 2014.
16. Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8nd Ed., Wiley Publications, 2019
17. Graham Solomons, T. W. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
18. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
19. I. L. Finar, Organic Chemistry, Vol I, 6th Ed, Pearson Education, 2002.
20. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Ed., Orient Longman, New Delhi, 1988.
21. Francis A. Carey and Richard J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, 5th Ed. 2007
22. Daniel E. Levy, Arrow Pushing in Organic Chemistry-An easy approach to understanding reaction mechanisms, Wiley Publications, 2008

23. Robert B. Grossman, The Art of Writing Reasonable Organic Reaction Mechanisms, 2nd Ed, Springer, 2003
24. L. G. Wade, Organic Chemistry, 6th Ed. Pearson, 2006
25. Francis A. Carey, Robert M. Giuliano, Organic Chemistry, 8th Ed. 2008
26. Peter Vollhardt, Neil Schore, Organic Chemistry-Structure and Function, 6th Ed. W. H. Freeman and Company, 2011
27. Thomas H. Lowry, Kathleen Schueller Richardson, Mechanism and Theory in Organic Chemistry, Harper and Row Publishers
28. Edwin S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Publications, 1959

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	1	2	3	1
2	3	1	3	3	1
3	3	1	3	3	1
4	3	1	3	3	1
5	1	1	2	3	1

Semester: IX **Course Type: Theory** **Course Code: CHE1093**
Credit: 4 **Course Title: Physical Chemistry-VI**

Course Outcomes		Level
CO-1	Enrich the knowledge about the fundamental concepts of thermodynamics(classical/statistical) and electrochemistry	**Remember**
CO-2	Recognize the electrochemical ideas at equilibrium and dynamics progress	**Understand**
CO-3	Apply different statistical methods	**Apply**
CO-4	Identify the different types of fuel cells and discuss their merits and demerits	**Create**

Unit-I Classical Thermodynamics

Introduction: Laws of thermodynamics, Entropy- Free Energy-Systems of Variable Compositions - Fugacity and Activity- Fugacity determination (graphical method and van der Waals equation of state) –Variation of Fugacity with respect to Temperature and Pressure - Maxwell's relations – significance, Partial molar properties – Chemical potential. Concept of absolute entropy and residual entropy

Thermodynamics of mixing: Thermodynamic functions of mixing, Clausius Inequality, Gibbs-Duhem-Margules equation, Konowaloff's rule, Henry's law, excess thermodynamic functions

Third law of thermodynamics: Nernst heat theorem, development of third law of thermodynamics, determination of absolute entropies using third law, entropy changes in chemical reactions. Thermodynamics of Irreversible Processes: Thermodynamics of irreversible processes with simple examples. phenomenological relations. Onsager reciprocal relations - principle of microscopic reversibility. Electrokinetic phenomena. Thermoelectric phenomena.

Unit-II Statistical Thermodynamics

Classical approach: Scope of statistical thermodynamics-probability theorem- starlings' approximation, phase space, microstate and macrostate, configuration, system, assembly and ensemble-different types of ensembles- permutations and combinations, thermodynamic probability, Maxwell-Boltzmann statistics and its limitations. Concept of partition functions and its relation with thermodynamic properties, evaluation of translational, rotational, vibrational and electronic partition functions. Sackur-Tetrode equation- thermodynamic properties of monoatomic gases. Quantum approach: Bose-Einstein Statistics, Bose-Einstein condensate, difference between first order and higher order phase transitions, liquid helium, supercooled liquids. Fermi-Dirac statistics- Application of Fermi-Dirac statistics to electron gas in metal and thermionic emission, Comparison of statistical models. Heat capacity of solids: Dulong - Petit law, Einstein's theory and its modification, Debye's theory of heat capacity of solids.

Unit-III Electrochemistry-II

Activity and Activity coefficient of electrolytes, ionic strength, Debye Huckel theory of strong electrolytes, Mean ionic activity coefficient. Debye Huckel theory-relaxation and electrophoretic effects, Debye-Huckel-Onsager equation and its derivation. Debye Falkenhagen effect. Wein effect. Ionic activity coefficients of strong electrolytes-Derivation of Debye-Huckel limiting law. Equilibrium Electrochemistry: EMF phenomena, cell potential and its measurement, reference electrodes. Electrochemical cells, concentration cells and activity coefficient determination, liquid junction potential. Determination of solubility. Redox indicators and redox titrations.

Unit-IV Electrochemistry-III

Dynamic Electrochemistry: Electrical double layer, various models of electrical double layer, Electrode polarization. Overpotential, hydrogen and oxygen overvoltage, theories of overvoltage, Butler-Volmer equation for simple electron transfer reactions, Tafel plot and its significance, Corrosion: stability of metals, Porbaus Diagram-Evan diagram-corrosion control and methods for prevention.

Unit-V Storage cells and Electroanalytical Techniques

Storage cells: Lead acid battery, lithium battery, nickel cadmium cell. Fuel Cell. Theory and working of fuel cell. H_2- O_2 fuel cell, methanol fuel cell, solid oxide fuel cells. Electroanalytical Techniques: Polarography – diffusion current, different current, supporting electrolyte, polarographic maxima, three electrode system. Amperometry – principles, types and applications. Cyclic voltammetry – principles, applications. Stripping voltammetry.

Reference Books:

1. R.P. Rastogi, R.R. Mishra, An introduction to Chemical Thermodynamics, Vikas Publishing house, 2009.
2. J. Rajaram, J.C. Kuriakose, Chemical Thermodynamics: Classical, Statistical and Irreversible, 1stEdn, S Chand and Co., 1999.
3. M.C. Gupta, Statistical Thermodynamics, New age international, 2007.
4. L.K. Nash, Elements of Classical & Statistical Mechanics, 2ndEd. Addison Wesley, 1972.
5. F.W. Sears, G.L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Addison Wesley, 1975.
6. J. Kestin, J.R. Dorfman, A Course in Statistical Thermodynamics, Academic Press, 1971.
7. John E. Freund. Modern elementary statistics, 2003, ISBN-13: 978-0131874398 20.
8. S. P. Gupta, Statistical Methods: S. Chand, 2014.
9. J. Bockris and A.K.N. Reddy, Modern Electrochemistry, 2ndEd, Wiley, New York, 1998.
10. D.R. Crow, Principles and Applications of Electrochemistry, Chapman & Hall, 3rdEdn., New York, 1994.
11. S. Glasstone, Introduction to Electrochemistry, Biblio Bazar, 2011.
12. B.K. Sharma, Electrochemistry, Krishna Prakashan, 1985.
13. A.I. Vogel, A Textbook of Quantitative Analysis including Instrumental Analysis, John Wiley & Sons, 1961.
14. H.H. Willard, J.A. Dean, L.L. Merritt, Instrumental Methods of Analysis, 7th Ed., Van Nostrand, 1965.
15. D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8thEdn. Saunders College Pub., 2007.
16. A.J. Bard, L.R Faulkner, Electrochemical Methods-Fundamentals and applications, 2ndEdn., Wiley India Ed.2004

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	1	3	2	2
2	3	1	3	2	2
3	2	2	3	2	2
4	3	2	2	2	2

Semester: IX **Course Type: Theory** **Course Code: CHE1094**
Credit: 4 **Course Title: Research Methodology**

Course Outcomes		Level
CO-1	Understand the principles of research, literature survey and writing research paper and thesis writing	**Understand**
CO-2	Gain knowledge on general terminology including various methods for the research	**Remember**
CO-3	Improve the numerical aptitude and computational knowledge in the basic of collection and presentation of data	**Apply**
CO-4	Acquire knowledge of safe laboratory practices by handling laboratory glassware, equipment and chemicals	**Apply**
CO-5	Analyze the idea about writing research papers and report	**Apply**

Unit-I Ethics in Research

Ethics, moral philosophy, nature of moral judgements and reactions. Scientific conduct - ethics with respect to science and research. Intellectual honesty and research integrity. Scientific misconducts - falsification, fabrication and plagiarism. Redundant publications - duplicate and overlapping publications. Selective reporting and misrepresentation of data.

Unit-II Literature Survey

Importance of literature survey, planning a literature search, identifying key concepts and key words, locating relevant literature and reliability of a source.
Science Citation Index–Journal Impact factors, h-index, g-index, i10 index, Chemical abstracts–UGC infonet, E-Journals and books–Search engines and databases

Unit-III Design of Experiments and Data Analysis

Aim, objectives, expected outcome, and methodology to be adopted. Importance of reproducibility of results. Objectives and basic principles of designs of experiments. Data analysis: Accuracy, precision, significant figures, use of calculation in the estimation of errors. Data presentation - using graphs, in tables, schemes and figures. Software for drawing. Bibliography tools.

Unit-IV Publication Ethics

Best practices and standards, conflicts of interest, publication misconduct, unethical behaviour and related problems. Authorship and contributorship. Identification of publication misconduct, complaints and appeals.

Unit-V Research Communication

General aspects of scientific writing - reporting practical and project work, writing literature survey and reviews, organizing a poster display, oral presentation. Guidelines for manuscript writing - abstract, introduction, methodology, results and discussion, conclusion, acknowledgement, references and citation. Writing research reports. Intellectual property (IP) and intellectual property rights (IPR).

Reference Books:

1. Bird, A., 2006. Philosophy of science. Routledge.
2. A.I. Vogel, “Quantitative Inorganic Analysis”, 3rd Ed., ELBS Longman London

3. J. March, 'Advanced Organic Chemistry; Reactions, Mechanisms and Structure', 6th Ed., Wiley– Interscience, 2016
4. MacIntyre, A., 2017. A short history of ethics: A history of moral philosophy from the Homeric age to the twentieth century. University of Notre Dame Press.
5. Chaddah, P., 2018. Ethics in Competitive Research: Do not get scooped; do not get plagiarized.
6. Bordens, K.S. and Abbott, B.B., 2002. Research design and methods: A process approach. McGraw-Hill.
7. Kothari C.R., 2020. Research methodology methods and Techniques. New Age International Publishers.
8. Thomas, C.G., 2021. Research methodology and scientific writing. Thrissur: Springer.

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	1	2	3	1
2	3	1	3	3	1
3	3	1	3	3	1
4	3	1	3	3	1
5	1	1	2	3	1

Semester: IX **Course Type: Practical** **Course Code: CHE1095**
Credit: 4 **Course Title: Inorganic Chemistry Laboratory-IV**

Course Outcomes		Level
CO-1	Identify the familiar and less familiar cations by semi-micro qualitative analysis	**Analyze**
CO-2	Ensures the students to acquire knowledge and have hands on experience in multistep inorganic compound synthesis and characterize them using spectroscopic techniques	**Skills**
CO-3	Apply the knowledge for performing experiment scientifically and safely to enrich the understanding about experiments in lab work	**Understand**
CO-4	Perform the preparation of inorganic complexes and purify them	**Apply**
CO-5	Gain knowledge on working principle of cyclic voltammetry and differential pulse voltammetry techniques and determine the electrochemical properties of complexes	**Knowledge**

I: Semi-micro qualitative analysis of a mixture containing two common and two rare – cations (any three salt mixtures)

II: Preparation of the following compounds and their Characterization (any seven experiments)

1. Tetramminecopper (II) sulphate.
2. Potassium trioxalatochromate (III)
3. Cis- and trans-potassium dioxalatediaquachromate(III)
4. Hexaamminenickel(II) chloride complex
5. Synthesis and study of Tris(oxalato)iron(III) potassium salt by Cyclic Voltammetry (CV) and Differential Pulse Voltammetry (DPV), and determination of the following: the formal reduction potential (Eo'); the number of electrons transferred in the redox process (n); electrochemical reversibility.
6. Synthesis and study of Mn^{III}(Salen)Cl by Cyclic Voltammetry and Differential Pulse Voltammetry (DPV), and determination of the following: the formal reduction potential (Eo'); the number of electrons transferred in the redox process (n); electrochemical reversibility.
7. Preparation and determination of the effective magnetic moment and number of unpaired electrons in $Mn(acac)_3$.
8. Preparation and determination of the aquation rate of $[Co(NH_3)_5Cl]Cl_2$.
9. Preparation and resolution of the optically active compound $[Co(en)_3]^{3+}$.
10. Control synthesis of copperoxalate hydrate complex; kinetic vs. thermodynamic factors
11. Bioanalytical techniques – Monitoring the cleavage of DNA and protein by metal complexes using Gel electrophoresis techniques – Agarose and PAGE (Demo only).

Reference Books:

1. J. Elias, A Collection of Interesting General Chemistry Experiments, Universities Press, Sangam Books Ltd, 2002.
2. J. D. Woollins, , Inorganic experiments, 3rd edition, Wiley-VCH Verlag GmbH @ Co. KGaA, 2012.
3. M. Hein, J. N. Peisen and R. L. Miner, Foundations of College Chemistry in the Laboratory, John Wiley and Sons, 2011.

4. G. S. Girolami, T. B. Rauchfuss and R. J. Angelici, Synthesis and Technique in Inorganic Chemistry: A Laboratory Manual, 3rd edition, University Science Books, 1999.
5. W. L. Jolly, The Synthesis and Characterization of Inorganic Compounds, Prentice-Hall, Inc.1970.
6. In-house Laboratory Manual, Department of Chemistry, CUTN.
7. Ghoshal, Mahapatra and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.
8. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
9. J. Mendham, Vogel's Quantitative Chemical Analysis, Pearson, 2009.
10. Ghoshal, Mahapatra and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.
11. V. Venkateswaran, R.Veerasamy A. R Kulandaivelu, Basic principles of Practical Chemistry, 2nd edition, New Delhi, Sultan Chand & sons, 2016.

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	1	2	2	2	3
2	2	3	3	2	3
3	3	3	1	2	3
4	3	2	3	3	3
5	2	1	3	1	2

Semester: X **Course Type: Practical** **Course Code: CHE1101**
Credit: 4 **Course Title: Research Project**

Course Outcomes		Level
CO-1	Understanding the nature of research problems and identifying the related area of knowledge	**Understand**
CO-2	Analyze literature reports in order to identify the methodology to solve the research problem	**Apply**
CO-3	Analyze data and synthesize research findings	**Apply**
CO-4	Demonstrate capacity to lead and manage change through collaboration with others	**Apply**

The student shall pursue research project for the whole semester under the allotted guide. The project report shall be submitted in the form of dissertation and the evaluation will be based on the performance in the lab and the final presentation of the research work done.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	2	2	2	2
2	3	3	3	3	3
3	3	3	3	3	3
4	3	3	3	3	3

List of Electives Courses

Course Code	Title of the Course	Credits
CHEE01	Principles of Polymer Science	4
CHEE02	Principles of Fluorescence Spectroscopy	4
CHEE03	Asymmetric Catalysis	4
CHEE04	Essentials of Carbohydrate Chemistry	4
CHEE05	Organic Electronics	4
CHEE06	Photochemistry in Molecules and Materials	4
CHEE07	Medicinal Inorganic Chemistry	4
CHEE08	Organic Semiconductors	4
CHEE09	Advances in Polymer Science	4
CHEE10	Advances in Carbohydrate Research	4
CHEE11	Advanced Organic Materials and Catalysis	4
CHEE12	Chemistry of CH Activation	4
CHEE13	Advanced Bio-inorganic Chemistry	4
CHEE14	Principles of Biochemistry	4
CHEE15	Mathematics for Chemists and Biologists	4
CHEE16	Electrochemical Energy Systems	4
CHEE17	Fundamentals of Analytical Chemistry	4
CHEE18	Computational Chemistry	4
CHEE19	Advanced NMR Techniques	4
CHEE20	Organometallics, Catalysis and Inorganic Spectroscopy	4
CHEE21	Applications of Computational Methods in Chemistry	4
CHEE22	Chemical Lab Safety and Management	4
CHEE23	Advanced Organic Synthesis	4
CHEE24	Green Chemistry	4
CHEE25	Advanced Topics in Organometallic Chemistry	4
CHEE26	Industrial Chemistry	4
CHEE27	Advanced Organic Nanomaterials	4
CHEE28	Computer software for Chemists	4
CHEE29	Selected Experiments in Applied Chemistry	4
CHEE30	Luminescence Spectroscopy for Advanced Research	4
CHEE31	Nanoscience and Technology	4

*New electives will be appended based on the availability of course instructor.
Electives will be offered based on the individual faculty's availability